

AD# 43324

AD632787

PURDUE RESEARCH FOUNDATION

Project No. 3684

**AN EXPERIMENTAL INVESTIGATION
ON THE EFFECT OF SUBSONIC INLET
MACH NUMBER ON THE PERFORMANCE
OF CONICAL DIFFUSERS**

by

Robert V. Van Dewoestine

Robert W. Fox

**SCHOOL OF MECHANICAL ENGINEERING
FLUID MECHANICS GROUP
PURDUE UNIVERSITY**

Technical Report FMTR -66-1

February 1966

**ARMY RESEARCH OFFICE (DURHAM)
DA Project No. 200 1050 1B700 / ARO(D) Project No. 4332
Contract No. DA-31-124-ARO(D)-138**

**CLEARINGHOUSE
FOR FEDERAL SCIENTIFIC AND
TECHNICAL INFORMATION**

Hardcopy

Microfilm

\$3.00

\$1.75

79

as

ARCHIVE COPY

Book 1

Purdue Research Foundation

Lafayette, Indiana

DA Project No. 200 1050 1B700 / ARO(D) Project No. 4332

School of Mechanical Engineering

Fluid Mechanics Group

Technical Report FMTR - 66 - 1

**AN EXPERIMENTAL INVESTIGATION ON THE EFFECT OF SUBSONIC
INLET MACH NUMBER ON THE PERFORMANCE OF CONICAL DIFFUSERS**

Contract No. DA-31-124-ARO(D)-138

by

Robert V. Van Dewoestine

Robert W. Fox

December 1966

Requests for additional copies by Agencies of the Department of Defense, their contractors, and other Government agencies should be directed to:

**Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Virginia**

Department of Defense contractors must be established for ASTIA services or have their "need-to-know" certified by the cognizant military agency of their project or contract.

ACKNOWLEDGEMENTS

This research was sponsored by the United States Army through the Army Research Office (Durham), under contract number DA-31-124-ARO(D)-138. Their financial support is gratefully acknowledged.

The work reported herein formed the basis of an MS thesis in Mechanical Engineering at Purdue University.

CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	v
NOMENCLATURE	vii
ABSTRACT	viii
INTRODUCTION	1
EXPERIMENTAL FACILITY	5
RESULTS	11
CONCLUSIONS	32
REFERENCES	34
APPENDICES	
Appendix A. Data and Calculated Performance Parameters for Current Investi- gation	35
Appendix B. Tabulation of Diffuser Perfor- mance at Selected Mach Numbers and cross-plots of Data Used in Plotting Performance Maps	55
Appendix C. Method of Obtaining Performance Maps	66
Appendix D. Discussion of Diffuser Choking	67

LIST OF TABLES

Table	Page
1. Thread Movements and Their Interpretation	10
A1. Data Summary for $2\phi = 2.0$ and $N/R_1 = 8.0$	36
A2. Data Summary for $2\phi = 2.0$ and $N/R_1 = 16.0$	37
A3. Data Summary for $2\phi = 2.0$ and $N/R_1 = 32.0$	38
A4. Data Summary for $2\phi = 4.0$ and $N/R_1 = 4.0$	39
A5. Data Summary for $2\phi = 4.0$ and $N/R_1 = 8.0$	40
A6. Data Summary for $2\phi = 4.0$ and $N/R_1 = 16.0$	41
A7. Data Summary for $2\phi = 4.0$ and $N/R_1 = 32.0$	42
A8. Data Summary for $2\phi = 8.0$ and $N/R_1 = 2.0$	43
A9. Data Summary for $2\phi = 8.0$ and $N/R_1 = 4.0$	44
A10. Data Summary for $2\phi = 8.0$ and $N/R_1 = 8.0$	45
A11. Data Summary for $2\phi = 8.0$ and $N/R_1 = 16.0$	46
A12. Data Summary for $2\phi = 8.0$ and $N/R_1 = 26.8$	47
A13. Data Summary for $2\phi = 15.8$ and $N/R_1 = 2.0$	48
A14. Data Summary for $2\phi = 15.8$ and $N/R_1 = 4.0$	49
A15. Data Summary for $2\phi = 15.8$ and $N/R_1 = 8.0$	50
A16. Data Summary for $2\phi = 15.8$ and $N/R_1 = 13.4$	51
A17. Data Summary for $2\phi = 31.2$ and $N/R_1 = 2.0$	52
A18. Data Summary for $2\phi = 31.2$ and $N/R_1 = 4.0$	53
A19. Data Summary for $2\phi = 31.2$ and $N/R_1 = 6.7$	54
B1. Diffuser Performance at Selected Mach Numbers . .	65

LIST OF FIGURES

Figure	Page
1. Lines of First Appreciable Stall and Lines of Maximum C_{pp} at Constant Length Ratio for Conical and Plane-Walled Diffusers (Taken from Reference 2).	3
2. Experimental Facility.	6
3. Detail of Nozzle and Straight Section.	7
4. Effect of Inlet Mach number on Flow Regimes in Conical Diffusers.. . . .	12
5. Diffuser Performance vs. Inlet Mach Number for $AR = 1.30$	16
6. Diffuser Performance vs. Inlet Mach Number for $AR = 1.64$	17
7. Diffuser Performance vs. Inlet Mach Number for $AR = 2.43$	18
8. Diffuser Performance vs. Inlet Mach Number for $AR = 4.48$	19
9. Diffuser Performance vs. Inlet Mach Number for $AR = 8.27$	20
10. Diffuser Performance vs. Inlet Mach Number for $2\phi = 2^\circ$	22
11. Diffuser Performance vs. Inlet Mach Number for $2\phi = 4^\circ$	23
12. Diffuser Performance vs. Inlet Mach Number for $2\phi = 8^\circ$	24
13. Diffuser Performance vs. Inlet Mach Number for $2\phi = 15.8^\circ$	25
14. Diffuser Performance vs. Inlet Mach Number for $2\phi = 31.2^\circ$	26
15. Performance Map for Conical Diffusers with $M_1 = 0.25$	28

Figure

Page

16. Performance Map for Conical Diffusers with $M_1 = 0.55$	29
17. Performance Map for Conical Diffusers with $M_1 = 0.70$	30
18. Diffuser Performance vs. AR-1 for Constant N/R_1 at $M_1 = 0.70$	31

Appendix B

B1. C_{PR} vs N/R_1 at constant AR for $M_1 = 0.25$	56
B2. C_{PR} vs AR at constant 2ϕ for $M_1 = 0.25$	57
B3. C_{PR} vs 2ϕ at constant N/R_1 for $M_1 = 0.25$	58
B4. C_{PR} vs N/R_1 at constant AR for $M_1 = 0.55$	59
B5. C_{PR} vs AR at constant 2ϕ for $M_1 = 0.55$	60
B6. C_{PR} vs 2ϕ at constant N/R_1 for $M_1 = 0.55$	61
B7. C_{PR} vs N/R_1 at constant AR for $M_1 = 0.70$	62
B8. C_{PR} vs AR at constant 2ϕ for $M_1 = 0.70$	63
B9. C_{PR} vs 2ϕ at constant N/R_1 for $M_1 = 0.70$	64

NOMENCLATURE

A	Area
AR	Area ratio = (outlet area)/(inlet area)
C_{PR}	Performance = $(P_2 - P_1)/q_1$
C_{PR_i}	Ideal performance = $(P_2 - P_1)_i/q_1$
M	Mach Number
N	Diffuser length along centerline
P	Static pressure
q	Mean dynamic pressure = $\frac{1}{2}\rho U^2$
R	Diffuser radius
U	Free stream velocity
u	Velocity at any point
W	Diffuser width - two-dimensional, plane-walled
X	Distance along centerline from diffuser inlet
δ^*	Displacement thickness of boundary layer
η	Effectiveness = $(P_2 - P_1)/(P_2 - P_1)_i$
θ	Momentum thickness of boundary layer
ρ	Density
2ϕ	Total divergence angle

Subscripts

i	Ideal
0	Stagnation
1	Diffuser inlet plane
2	Diffuser outlet plane

ABSTRACT

Experiments have been performed to determine the effect of subsonic inlet Mach number on diffuser performance and flow regimes for a wide range of conical diffuser geometries.

For incompressible flow the line of first appreciable stall, line a-a, is essentially that found by McDonald and Fox (Reference 2). As the Mach number is increased, the flow tends more toward separation in all cases.

Diffuser performance maps are presented for three different inlet Mach numbers ($M_1 = 0.25, 0.55, 0.70$). There is no significant variation in the location of the line of maximum performance at constant length to inlet radius ratio, line a-a, with inlet Mach number. For $M_1 = 0.25$ line a-a of the present study is virtually identical to that found in the earlier water flow studies of McDonald and Fox (Reference 2).

INTRODUCTION

Performance of conical diffusers is dependent on both flow and geometric variables. Previous work has indicated that the geometric variables of importance are total divergence angle, 2ϕ , length to inlet radius ratio, N/R_1 , and area ratio, AR. The flow variables are more numerous and often somewhat more difficult to identify. In part they are inlet boundary layer thickness, Mach number, turbulence intensity, and Reynolds number. The large number of variables makes a generalized theory of diffusers difficult; considerable data are required to determine the effect of a single variables over a range of the other variables.

In the past many investigators have been more interested in improving the performance of a single diffuser rather than formulating any relationships for a wide range of geometries and flow conditions. A summary of previous investigations of two-dimensional, plane-walled diffusers is given by Kline, et al^{1*} for the case of steady, incompressible flow with a thin inlet boundary layer (compared to the inlet width of the diffuser). The summary includes observations of flow regime (degree of separation) and measurements of performance over a wide range of diffuser divergence angles and length ratios.

* Superscript numbers will be used to denote items in the List of References.

The results showed that flow regime was primarily dependent on the geometry of the diffuser, but that the performance depended on other variables as well. The results of Reference 1 were presented on coordinates of divergence angle versus length ratio. The location of "first appreciable stall" was designated as line a-a; the line of maximum pressure recovery for fixed N/W_1 was designated as line α - α . The location of these lines for two-dimensional, plane-walled diffusers is shown in Figure 1. McDonald and Fox² performed a systematic investigation of flow regimes and diffuser performance over a wide range of conical diffuser geometries. The location of lines a-a and α - α as presented in Reference 2 are also shown in Figure 1. Both of these studies were for incompressible flow and were primarily concerned with the effect of geometric variables on flow regimes and diffuser performance.

The purpose of this work is to extend the investigations of McDonald to regions of compressible flow; i.e., to determine the effect of subsonic inlet Mach number on flow regime and performance in conical diffusers. Several investigators (Ackeret³; Copp⁴; Little and Wilbur⁵; Naumann⁶; Scherrer and Anderson⁷) have taken data on the effects of Mach number on diffuser performance; however, these data are only for a small number of geometries grouped around the line of optimum performance; the values of the geometrical parameters employed in these earlier investigations are shown in Figure 1. It should be noted that in all cases the exit of the diffusers was joined to a tailpipe. This limited data indicated that

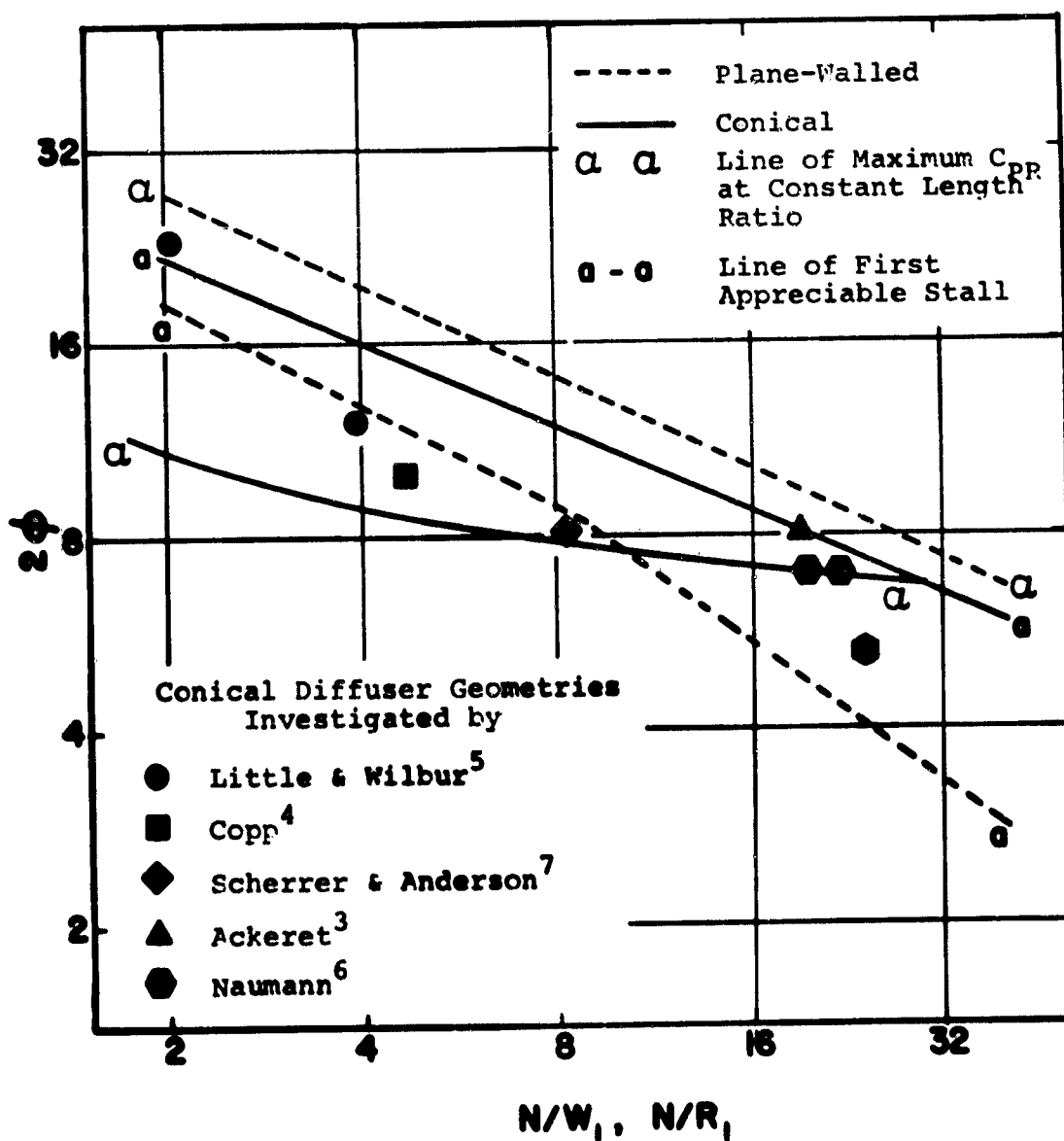


Figure 1. Lines of First Appreciable Stall and Lines of Maximum C_{PR} at Constant Length Ratio for Conical and Plane-Walled Diffusers (Taken from Reference 2)

there is little effect of Mach number on diffuser performance or flow regime until the flow becomes choked. In view of the limited data available, a systematic investigation was undertaken to determine the effect of subsonic inlet Mach number on diffuser performance and flow regime over a wide range of conical diffuser geometries.

In the present study the dependence of flow regime and performance on inlet Mach number was determined experimentally for the nineteen conical diffuser geometries employed in the work of McDonald and Fox². The results were then correlated with the geometric variables in an attempt to find useful relationships for predicting diffuser behavior under a given set of inlet conditions.

EXPERIMENTAL FACILITY

The arrangement and dimensions of the wind tunnel used in the present study are shown in Figure 2. The tunnel was of the blow through type. Air from a Spencer turbo-blower came through a 24 inch diameter pipe and into a transition section; the transition section changed the passage from the round pipe to a 20 inch x 20 inch square channel which served as an upstream plenum. This plenum section, containing flow straighteners and screens, was 32 inches in length. Flow entered the diffuser test sections through a converging nozzle designed according to Smith and Wang⁸. (The nozzle was designed from curve (a) of Reference 8; the nozzle contour was taken from a chart given by the authors and scaled up to the desired size.) The nozzle was bolted through the downstream face of the plenum and extended a distance of 7.86 inches upstream into the plenum. For ease of construction, the nozzle was fabricated in two pieces as shown in Figure 3. The constant area section extended for 5 inches beyond the plenum wall. The inside of the straight section was machined and polished to insure close matching with both the end of the nozzle and the diffuser. The diffuser was then bolted to the straight section with the alignment maintained by two pins. The exit of the diffuser was fastened to a plexiglass plate which was in turn bolted to

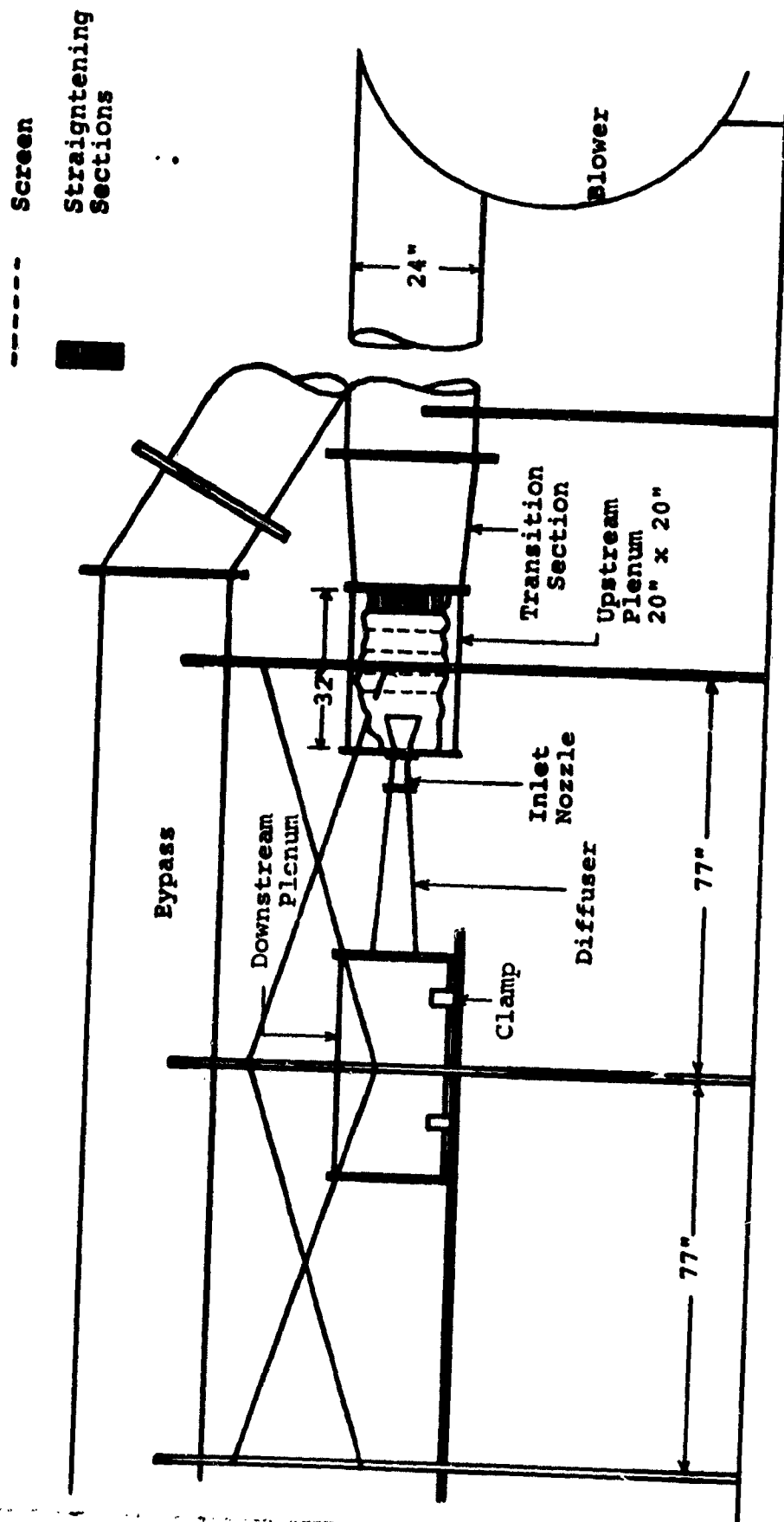


Figure 2. Experimental Facility

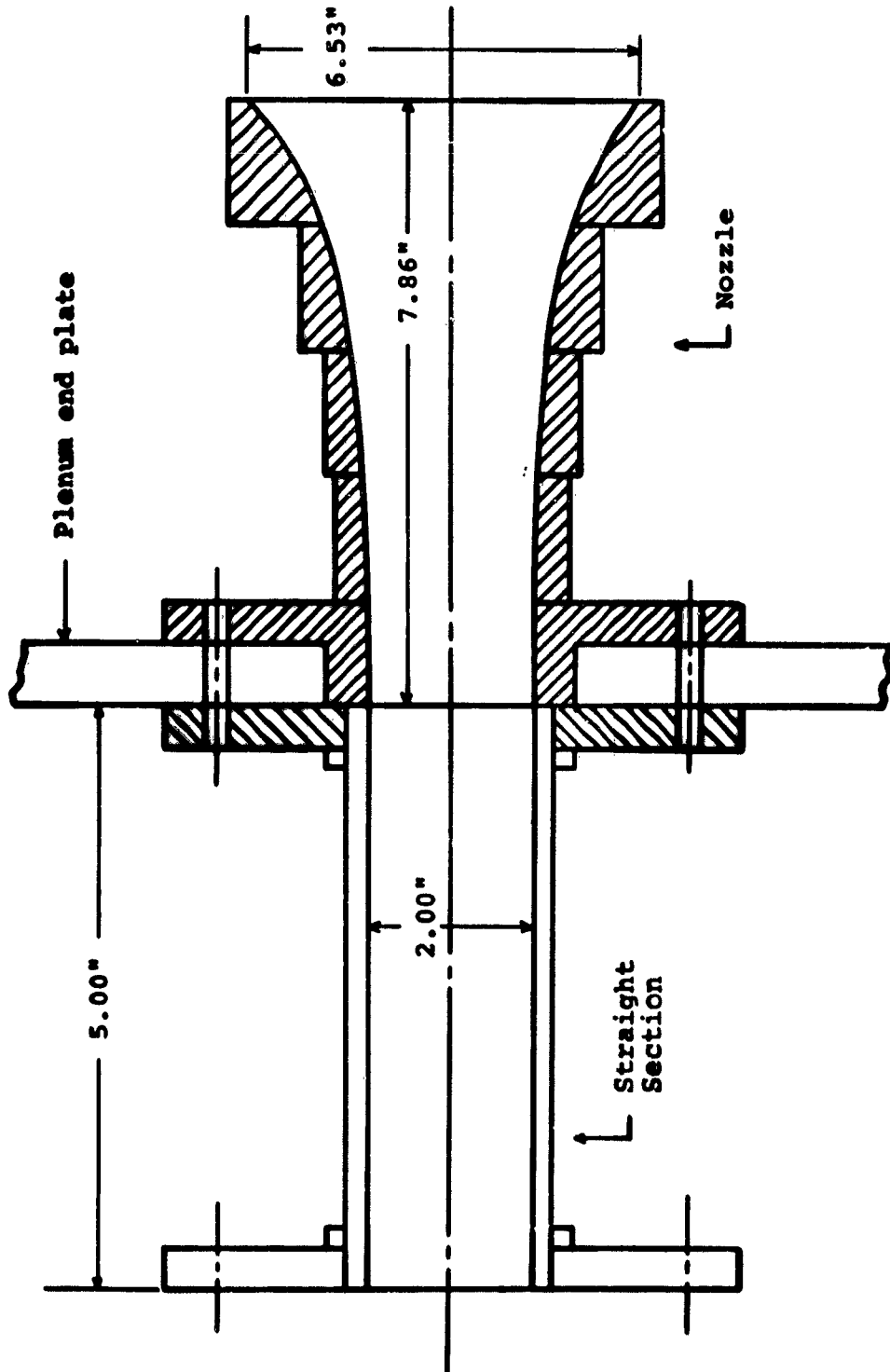


Figure 3. Inlet Nozzle

the downstream section of the tunnel. The attachment was made so that the exit plane of the diffuser was flush with the plate. The downstream part of the tunnel was clamped to the plywood sheet upon which it rested in such a manner that it could be moved back and forth to allow for different diffuser lengths. The downstream plenum was 42 inches long; the flow exhausted to the room.

Wall pressure measurements were taken along the diffuser length; the pressure tap locations are given in Appendix A. Tygon tubing was run from the pressure taps to a bank of mercury manometers. The manometers had a least count of 0.05 inches and this was used as the basic module of the readings taken. Since there was usually a fluctuation in the readings of the manometers of 0.025 inches, it was felt that it would be unrealistic to take readings closer than the least count.

During the early runs a great deal of trouble was encountered with separation and irregular flow in diffusers which should have run smoothly. This was traced to disturbances in the air at the exit of the blower. To correct this condition, a set of flow straighteners and 4 screens were installed in the upstream plenum. The straighteners consisted of a $1\frac{1}{2}$ inch square grid of sheet metal 4 inches long. This broke up the large disturbances and the screens following the straighteners further reduced the scale of the disturbances. Three other steps were also taken which helped even more than the straighteners and screens. The butterfly valve on the blower outlet, which was at first used to control the air flow, was left wide open; the air flow was controlled

by a butterfly valve on the blower inlet. This eliminated the large vortex which was being shed off of the partially opened outlet valve. Through use of the bypass the blower power level was maintained above 150 kw. This put the blower above its surge point. Extraneous piping was removed from the blower inlet so that the blower inlet flow was reasonably uniform. With these precautions taken, the output of the blower became quite regular and at low speed the diffusers behaved as they had for McDonald and Fox².

The diffusers employed in the present work were those used by McDonald and Fox². The range of divergence angles and length ratios cover a wide range of diffuser geometries including the region of maximum diffuser performance. A description of the diffuser design and construction can be found in Reference 2 (page 37.).

The degree of separation (flow regime) in the diffusers was determined by observations of cotton threads taped to the diffuser walls. Threads were equally spaced around the circumference of the diffuser at several axial positions along the diffuser length. Each of the threads was reinforced with a slight amount of glue on the free end. Without the glue the threads tended to ravel in the high velocity air stream. To obtain the maximum sensitivity, the amount of glue used was kept to an absolute minimum. The degree of separation was determined according to the criteria of Table 1. The cases where separation was localized in one part of the diffuser (such as the downstream end) are noted in the data presentation.

Table 1. Flow Regime Criteria

<u>Movement and orientation of thread</u>	<u>Type of flow</u>	<u>Symbol</u>
Thread held near wall, pointing downstream, occasionally wiggling	Steady flow with occasional disturbance	-
Major part of time thread points downstream, wiggling; random flickering (thread quickly points upstream, then downstream again) indicating temporary and local separation	Intermittent transitory stall	I
Thread whips continually upstream and downstream, indicating rapid and chaotic occurrence and disappearance of separation	Local transitory stall	T
Thread whips upstream and downstream major part of time; thread held in upstream position wiggling at random intervals	Local transitory stall with intermittent fixed stall	TIF
Thread held upstream major part of time; temporary whipping at random intervals	Local fixed stall with intermittent transitory stall	FIT
Thread held upstream with end wiggling	Local fixed stall	F

RESULTS

The flow regime was determined in a given diffuser as a function of inlet Mach number. The flow regimes are indicated on Figure 4. The first symbol indicates the low speed flow regime; the second symbol indicates the flow regime at the highest inlet Mach number tested. The low speed results differed little from those of McDonald and Fox². However, with increasing inlet Mach number the flow tended more toward separation in all cases. In instances where this does not show on Figure 4, it is because the worsening of the flow was not enough to push it into the next flow regime category. Another item worthy of note is that as length was added to the diffusers, the flow tended to worsen only in the added section. In other words, the flow in the first 4 inches of an 8 degree, 4 inch diffuser tended to be the same as the flow in the first 4 inches of an 8 degree, 8 inch diffuser.

To determine performance the data were taken for each diffuser as the Mach number was increased incrementally up to a maximum. For about half the diffusers this maximum was at the point of local choking and for the others it was at the limit of the blower. In either case, the maximum inlet Mach number was always greater than 0.65. Data were taken for at least 10 values of the Mach number between low speed flow and the limit points. The data taken were the plenum (stagnation) pressure, diffuser inlet static pressure (in the

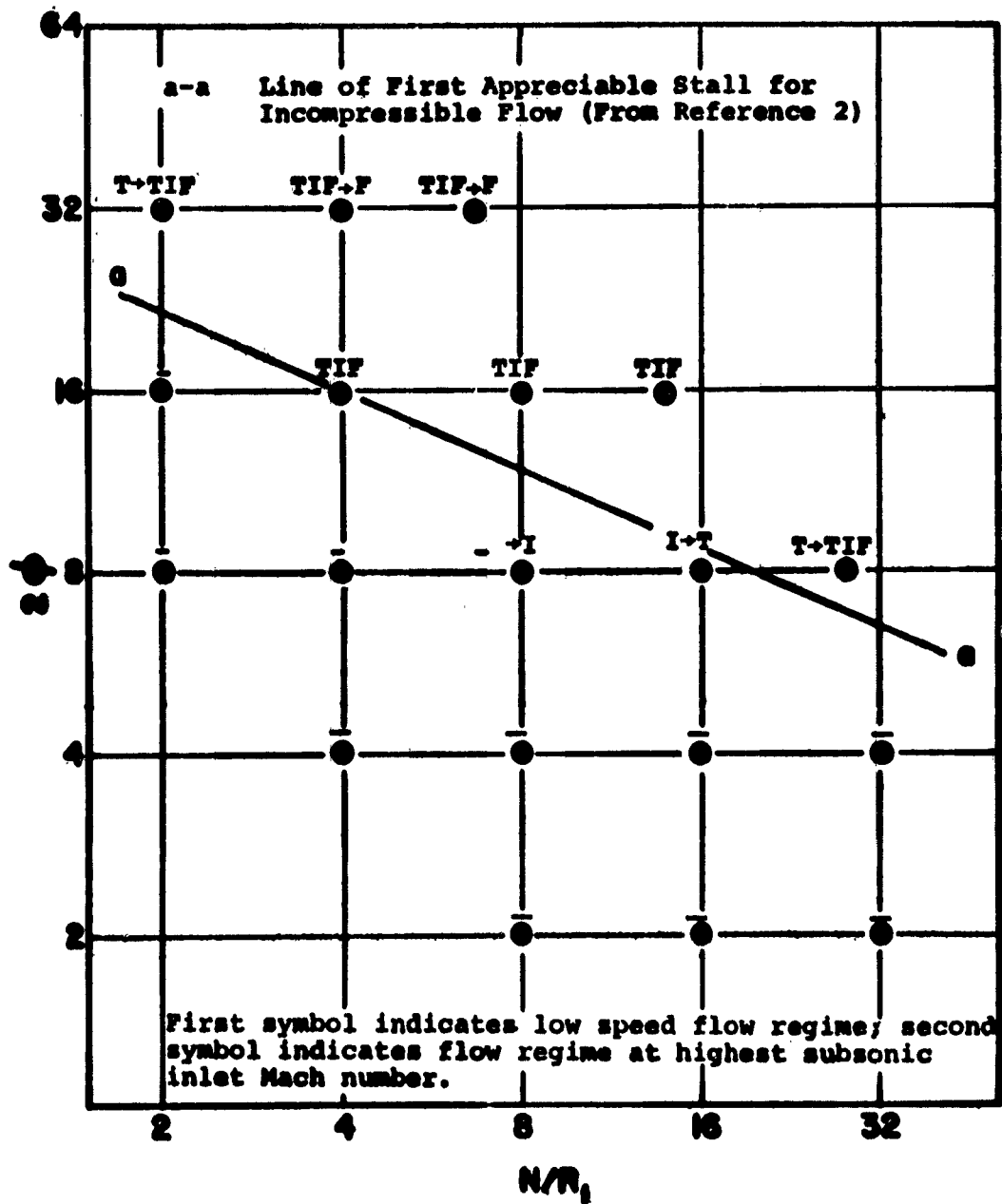


Figure 4. Effect of Inlet Mach Number on Flow Regimes in Conical Diffusers

constant area portion of the nozzle), the static pressures at stations along the diffusers and the downstream plenum pressure. From these the diffuser performance and the pressure profile along the diffuser could be obtained. All the data taken are summarized in Appendix A.

The tunnel system was checked to determine the inlet turbulence intensity and inlet boundary-layer thickness. A hot wire anemometer was used for both of these measurements. The equipment used was a constant current Flow Corporation model HWB 3. A single wire was mounted, calibrated and then used for all measurements. For an inlet free stream velocity of 160 fps the turbulence intensity was found to be at a rather high level of 10%. There was evidently a high turbulence level created in the blower that was only partially corrected by the screens and large contraction ratio.

The velocity profile was integrated to give the momentum and displacement thicknesses. For an inlet free stream velocity of 160 fps the ratio of momentum thickness and displacement thickness to inlet radius were 0.011 and 0.017 respectively. The actual boundary layer thickness was on the order of 0.06 inches.

In calculating the performance from the pressure data the following assumptions were made:

1. Friction in the nozzle is negligible and the nozzle flow is one-dimensional. This is reasonable because of the short distance involved. Thus, the one-dimensional isentropic relations can be used to calculate the Mach number at the diffuser entrance.

2. Stagnation conditions occur in the upstream section of the wind tunnel. Calculations showed a better than 100:1 velocity ratio between the test section and the upstream plenum. Thus, the upstream air is essentially stagnant with respect to the test section.

3. The static pressure at the exit of the diffuser is the same as that read by a static pressure tap located in the plane of the diffuser exit and 6 inches from its centerline.

Diffuser performance as a function of inlet Mach number was originally plotted on nineteen separate graphs, one for each diffuser. In general, the performance showed little variation over the range of Mach numbers tested. Close to choking, however, there is sudden, sharp decrease in performance.* This is very similar to the results obtained by previous investigators. Any systematic variation of diffuser performance with inlet Mach number seemed to be dependent on the line of first appreciable stall. Below the line of first appreciable stall the smaller angle diffusers with relatively smooth flow exhibited a slight upward trend in performance as the inlet Mach number was increased. This trend was not present in the diffusers close to the first appreciable stall line; in diffusers close to the first appreciable stall line performance is essentially constant until choking is reached. Above the line of first appreciable stall, the performance decreased with increasing Mach number. In general as the location above the line increased, the drop off in performance, with increasing inlet Mach number, increased.

* See Appendix D.

The separate performance curves were combined into sets for either constant area ratio, constant length ratio, or constant divergence angle. The results plotted for constant area ratio are presented in Figures 5-9. In Figure 5, all of the curves essentially fall on the same line. Examination of the flow regime chart shows that all three of the diffusers in the figure lie well inside the unseparated region. In Figure 6, all but one of the curves fall together. Examination of the flow regime chart shows that the diffuser with the lowest performance for all Mach numbers has a geometry which lies above the line of first appreciable stall. In Figure 7, the two geometries with the lower performance are located above the line of first appreciable stall; the diffuser showing the lowest performance lies at the greatest distance above the line. This same trend in diffuser performance is observed at increased area ratio as shown in Figures 8 and 9.

For a given area ratio, diffuser performance, at a given Mach number, is independent of diffuser angle (or length ratio) for diffuser geometries lying below the line of first appreciable stall. For a given area ratio, diffuser performance will drop off at all Mach numbers as one proceeds to geometries lying above line a-a. The drop off in performance increases with increasing distance above line a-a (increased flow separation). The consistency of these results can be taken as further substantiation of the location of the line of first appreciable stall in conical diffusers as presented by McDonald and Fox².

- - $2\phi = 2^\circ$, $N/R_1 = 8.0$
- - $2\phi = 4^\circ$, $N/R_1 = 4.0$
- △ - $2\phi = 8^\circ$, $N/R_1 = 2.0$

Points for $M = 0.0$ are from reference 2.

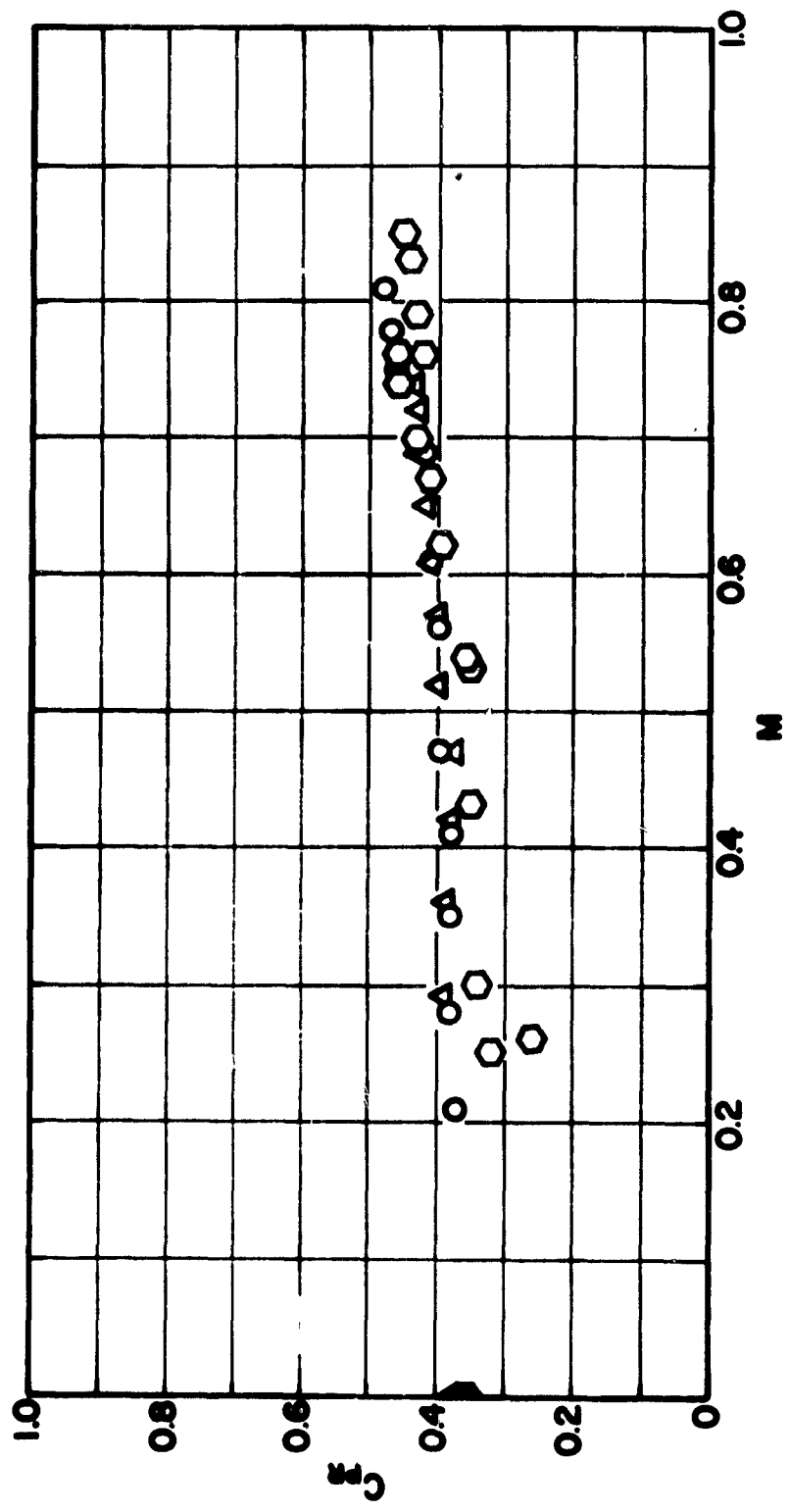
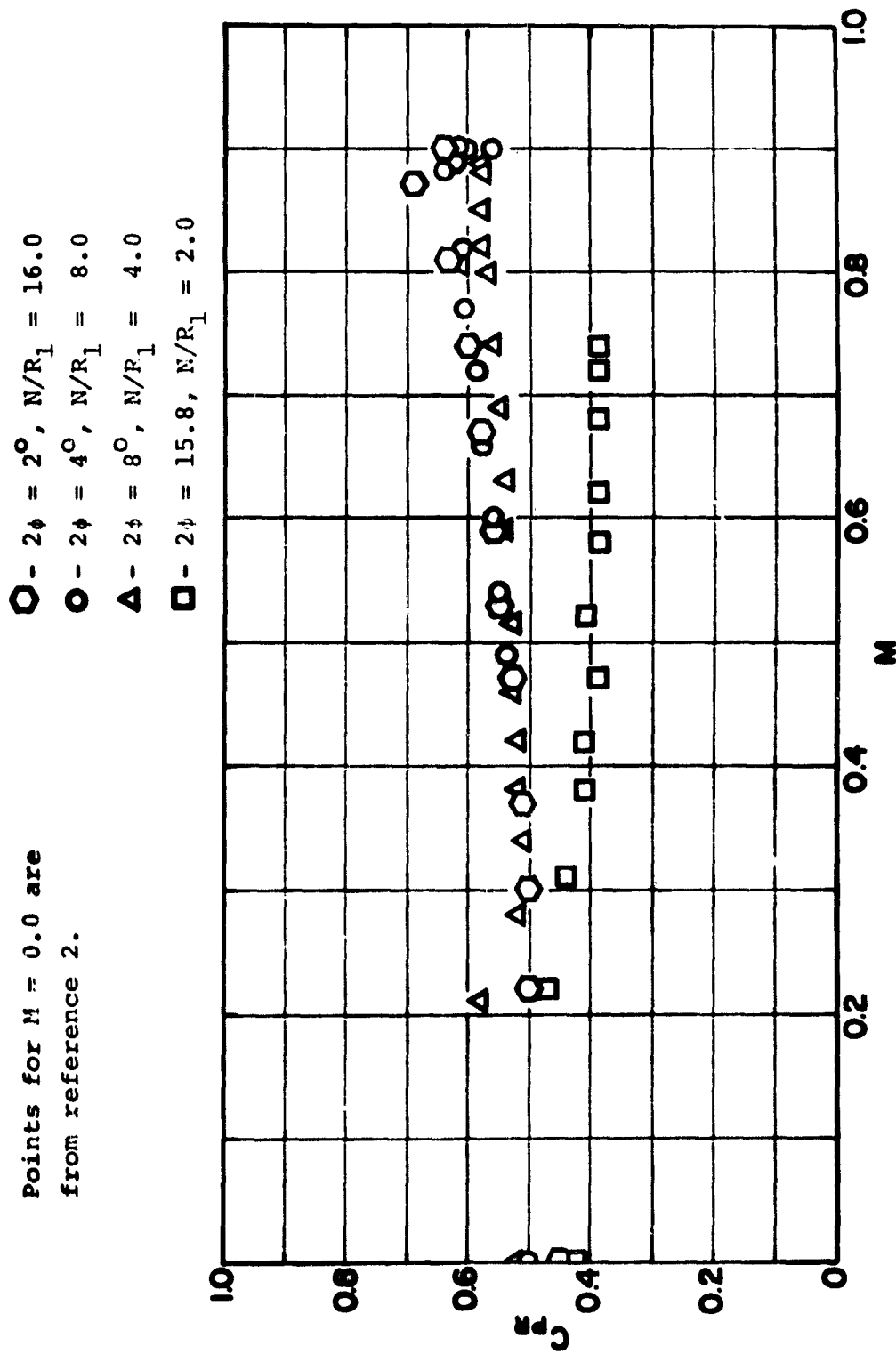


Figure 5. Diffuser Performance vs. Inlet Mach Number for $AR = 1.30$.

Figure 6. Diffuser Performance vs. Inlet Mach Number for $AR = 1.64$.

Points for $M = 0.0$ are
from reference 2.

- \odot - $2\phi = 2^\circ$, $N/R_1 = 32.0$
- \circ - $2\phi = 4^\circ$, $N/R_1 = 16.0$
- Δ - $2\phi = 8^\circ$, $N/R_1 = 8.0$
- \square - $2\phi = 15.8^\circ$, $N/R_1 = 4.0$
- ∇ - $2\phi = 31.2^\circ$, $N/R_1 = 2.0$

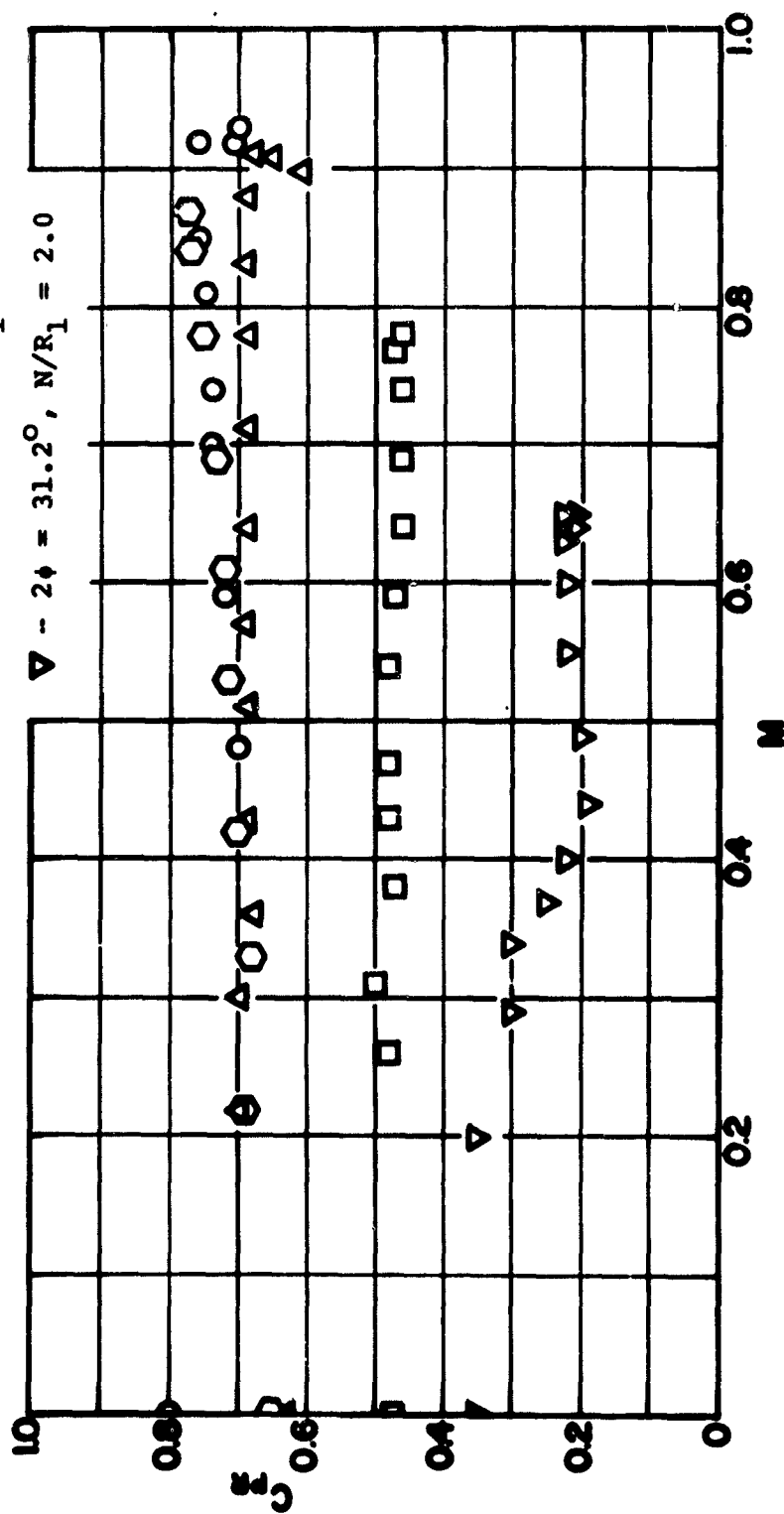


Figure 7. Diffuser Performance vs. Mach Number for $AR = 2.43$.

Points for $M = 0.0$ are
from reference 2.

- - $2\phi = 4^\circ$, $N/R_1 = 32.0$
- △ - $2\phi = 8^\circ$, $N/R_1 = 16.0$
- - $2\phi = 15.8^\circ$, $N/R_1 = 8.0$
- ▽ - $2\phi = 31.2^\circ$, $N/R_1 = 4.0$

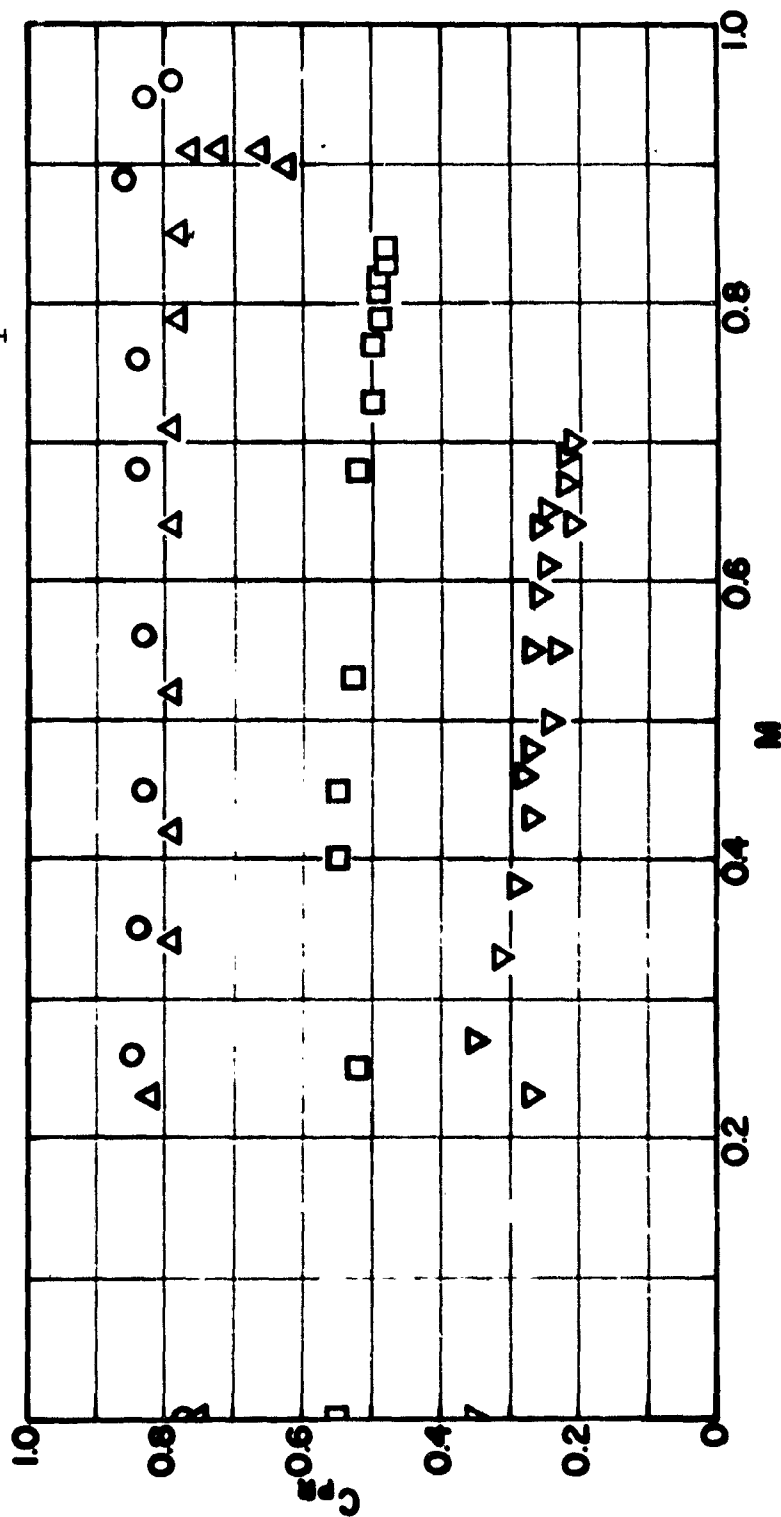


Figure 8. Diffuser Performance vs. Inlet Mach Number for $AR = 4.48$.

Points for $M = 0.0$ are
from reference 2.

$\Delta - 2\phi = 8^\circ, N/R_1 = 26.8$

$\square - 2\phi = 15.8^\circ, N/R_1 = 13.4$

$\circ - 2\phi = 31.2^\circ, N/R_1 = 6.7$

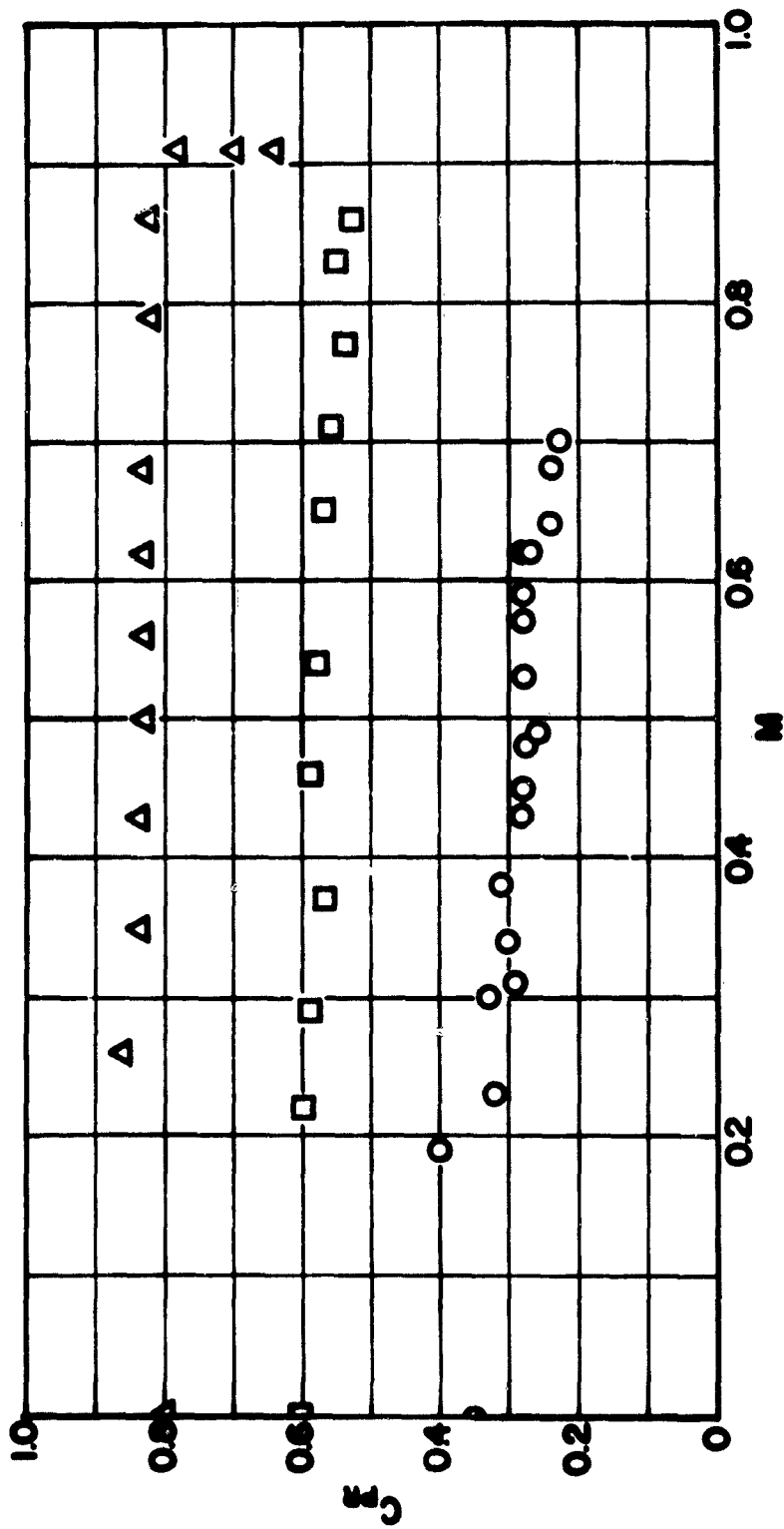


Figure 9. Diffuser Performance vs. Inlet Mach Number for $AR = 8.27$.

No systematic variation in diffuser performance as a function of Mach number was observed when the curves were plotted for constant length ratios. Consequently these plots are not reproduced here.

Figures 10-14 show diffuser performance versus inlet Mach number at constant divergence angle. On these plots the results are not as clear as those plotted for constant area ratio; however a systematic variation is evident. For a given divergence angle, the performance at any Mach number is a maximum for diffusers with the maximum area ratio. The spread of performance as a function of the area ratio for a given divergence angle decreases as the divergence angle is increased. At a divergence angle of 31.2 degrees, diffuser performance is uniformly low and essentially independent of area ratio at all Mach numbers.

Figures 15, 16, and 17 present performance maps for conical diffusers at Mach number of 0.25, 0.55 and 0.70 respectively. Lines of constant performance are presented on plots of area ratio versus length ratio. For a given value of M_1 , these constant performance contours were obtained from three different cross plots of the data^{*}; the data were plotted as C_{PR} vs N/R_1 at constant AR, C_{PR} vs AR at constant 2ϕ and C_{PR} vs 2ϕ at constant N/R_1 . A summary of the data employed and the actual cross plots are given in Appendix B.

The location of the line of maximum performance at constant diffuser length to inlet radius ratio, line α - α is shown on each of the performance maps. On Figure 15 the dashed line shows the location of line α - α as determined in

* See Appendix C.

Points for $M = 0.0$ are
from reference 2.

Δ - $N/R_1 = 8.0$, $AR = 1.30$
 \square - $N/R_1 = 16.0$, $AR = 1.64$
 ∇ - $N/R_1 = 32.0$, $AR = 2.43$

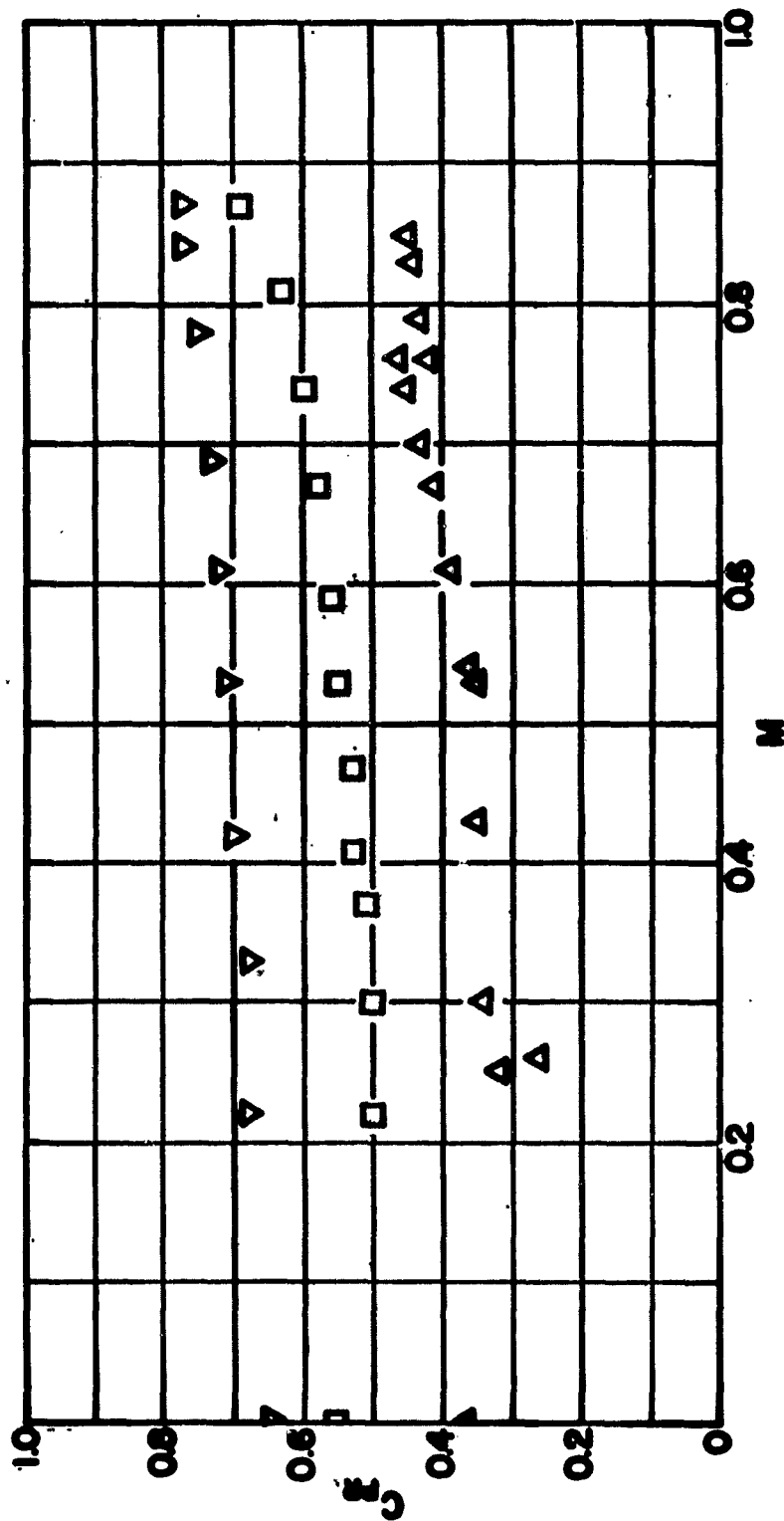


Figure 10. Diffuser Performance vs. Inlet Mach Number for $2\phi = 2^\circ$.

Points for $M = 0.0$ are
from reference 2.

- \circ - $N/R_1 = 4.0$, $AR = 1.30$
- \triangle - $N/R_1 = 8.0$, $AR = 1.64$
- \square - $N/R_1 = 16.0$, $AR = 2.43$
- ∇ - $N/R_1 = 32.0$, $AR = 4.48$

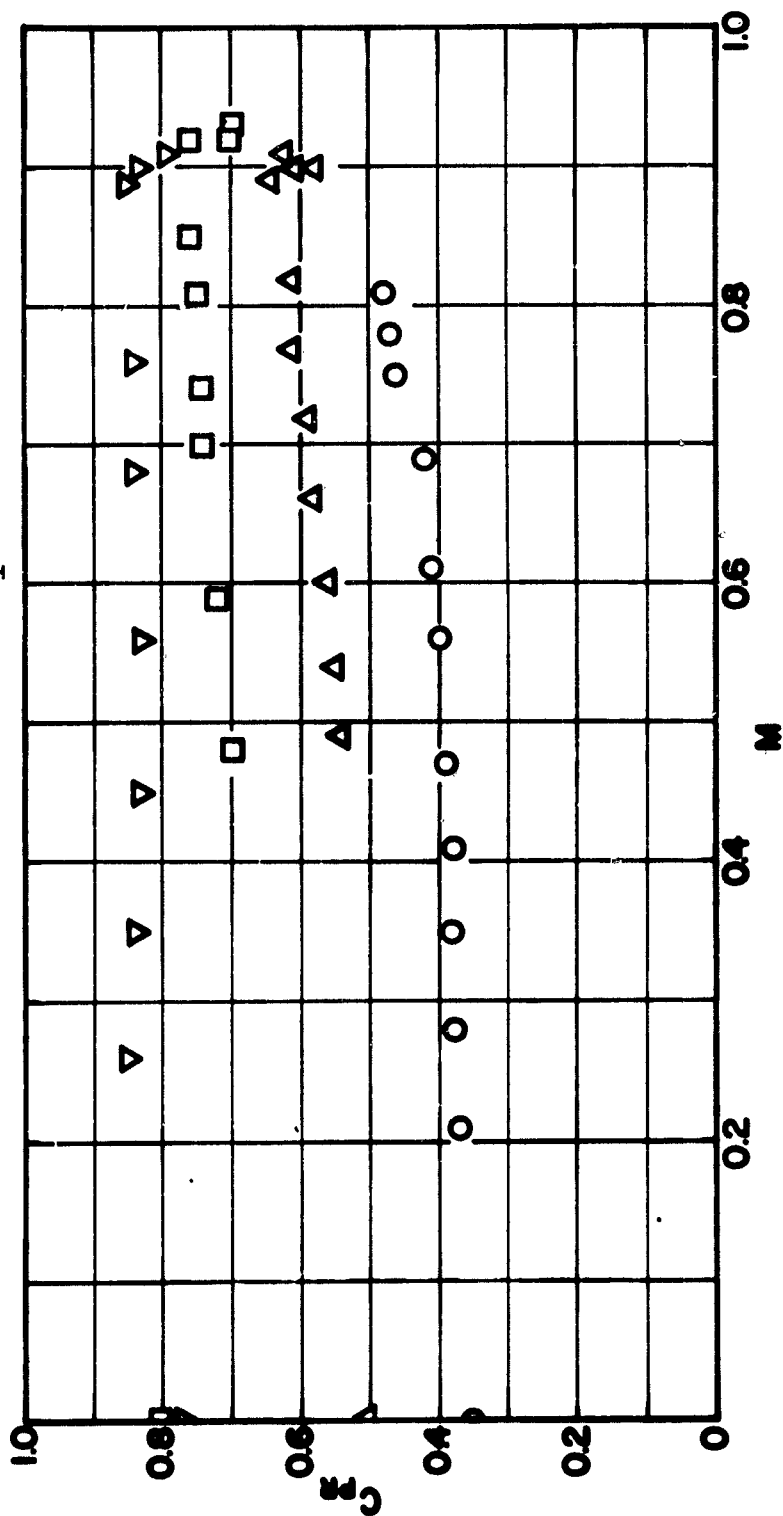


Figure 11. Diffuser Performance vs. Inlet Mach Number for $2\phi = 4^\circ$.

Points for $M = 0.0$ are
from reference 2.

○ - $N/R_1 = 2.0$, $AR = 1.30$

○ - $N/R_1 = 4.0$, $AR = 1.64$

△ - $N/R_1 = 8.0$, $AR = 2.43$

□ - $N/R_1 = 16.0$, $AR = 4.48$

▽ - $N/R_1 = 26.8$, $AR = 8.27$

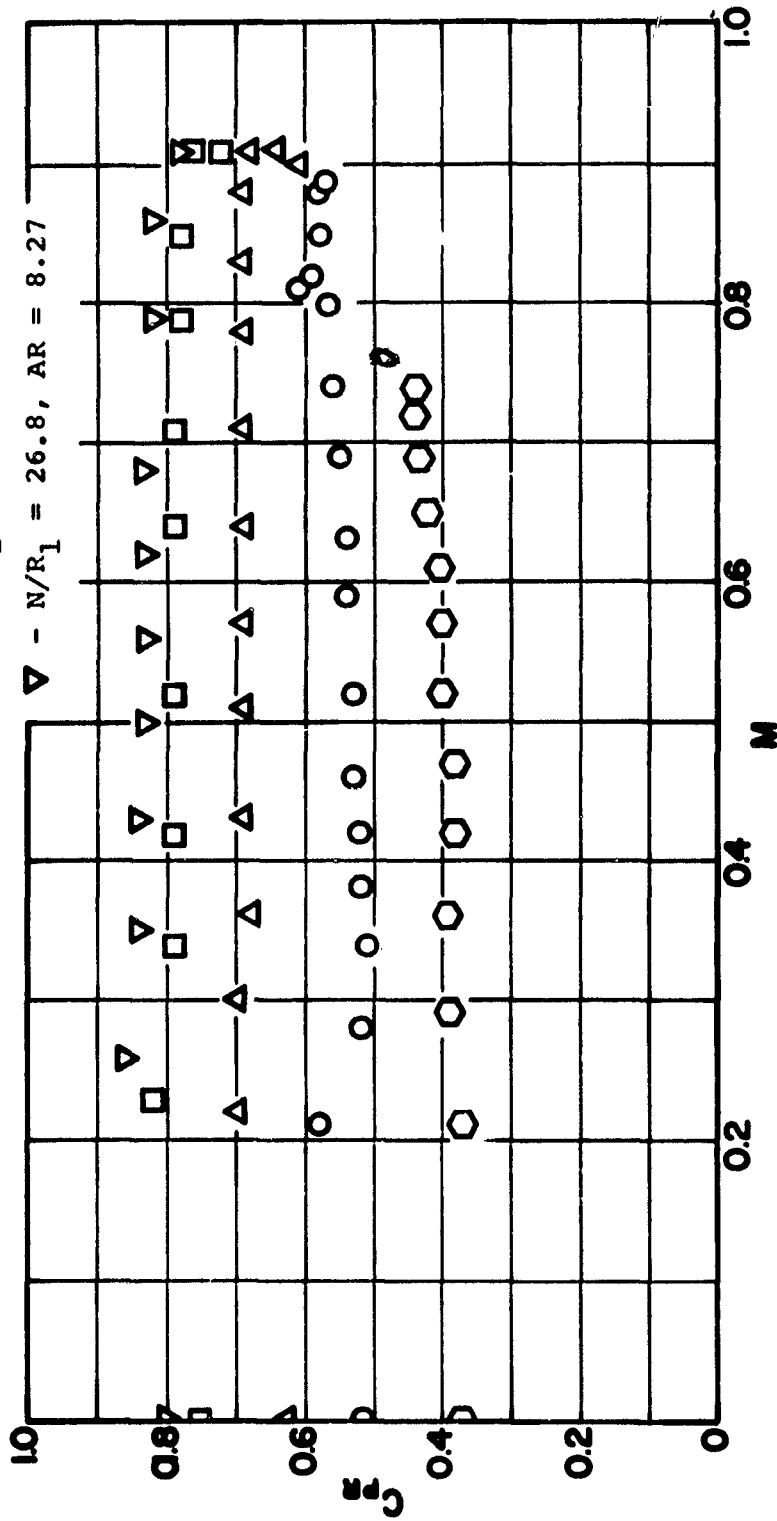


Figure 12. Diffuser Performance vs. Inlet Mach Number for $2\phi = 8^\circ$.

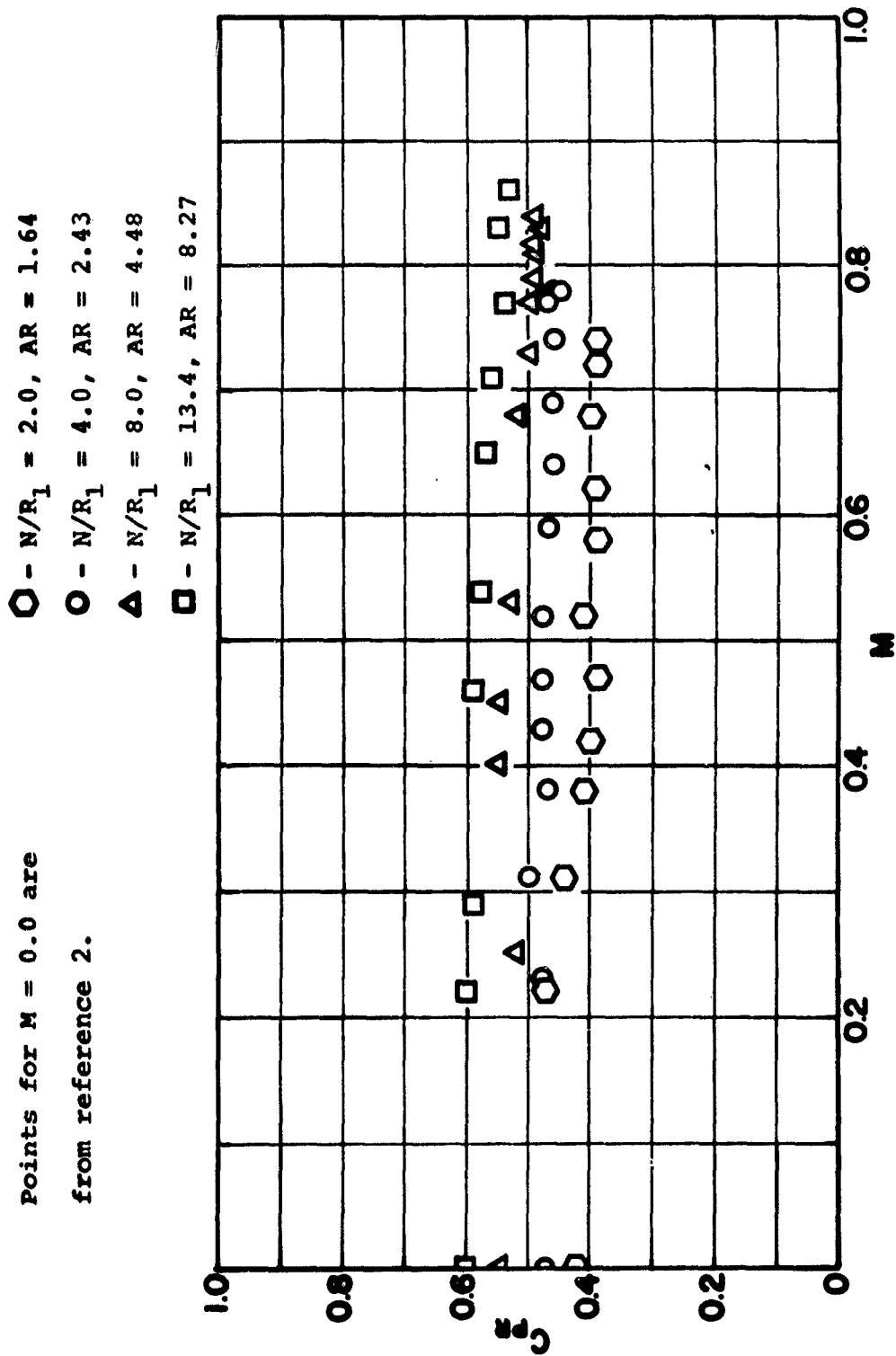


Figure 13. Diffuser Performance vs. Inlet Mach Number for $2\phi = 15.8^\circ$.

Points for $M = 0.0$ are
from reference 2.

- - $N/R_1 = 2.0$, $AR = 2.43$
- - $N/R_1 = 4.0$, $AR = 4.48$
- △ - $N/R_1 = 6.7$, $AR = 8.27$

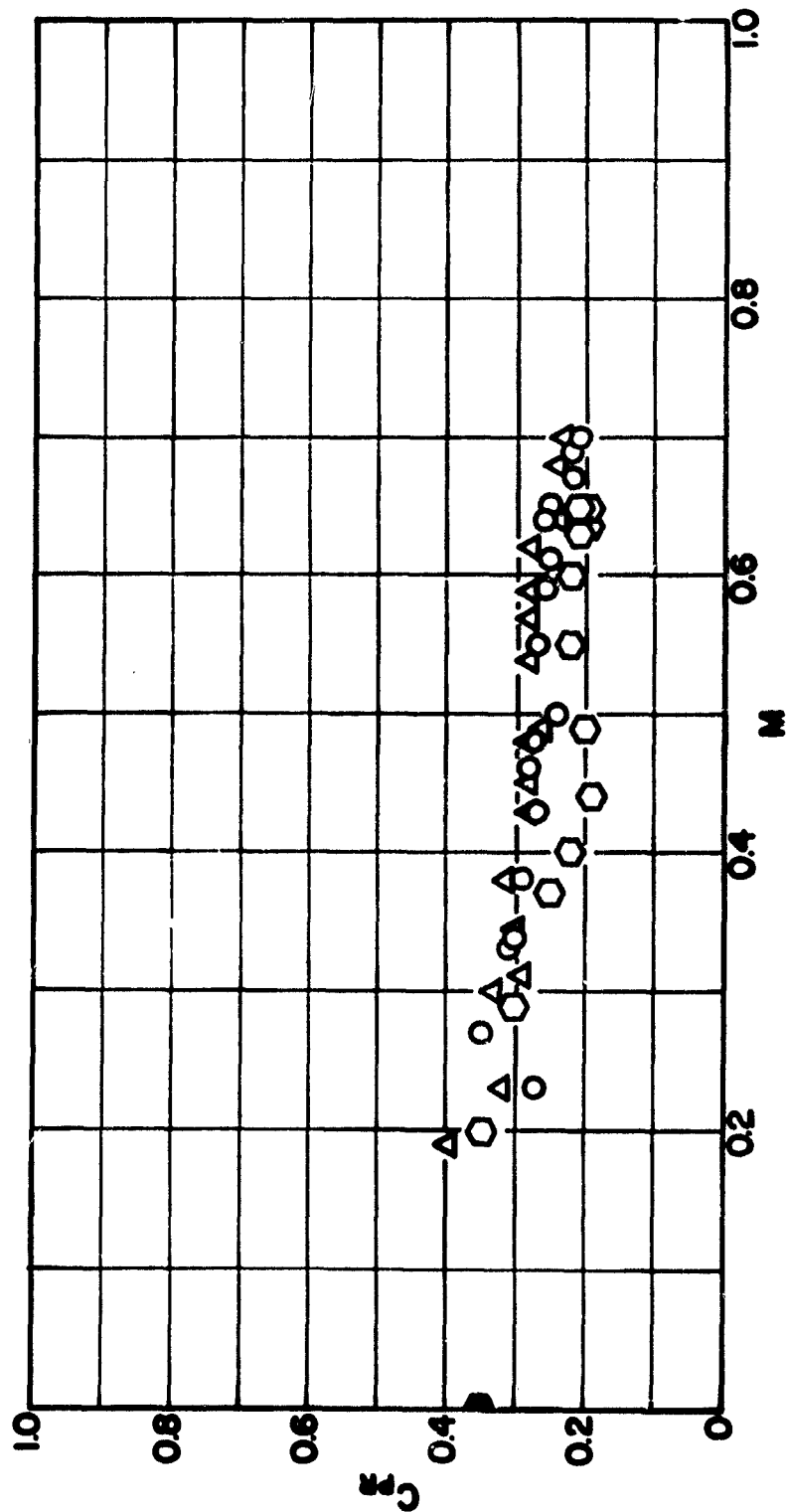


Figure 14. Diffuser Performance vs. Inlet Mach Number for $2\phi = 31.2^\circ$.

the water flow studies of McDonald and Fox². The agreement with the present air flow studies for incompressible flow is excellent. A comparison of Figures 15 and 16 shows that there is a slight upward shift in the location of the line α - α as the inlet Mach number is increased from 0.25 to 0.55. However the shift is within the uncertainty in the data. When the inlet Mach number is increased to 0.70, line α - α is slightly lower than that for $M_1 = 0.25$ (Compare Figures 15 and 17); again the shift is within the uncertainty in the data.

From the performance maps it can be seen that for a given inlet Mach number and diffuser area ratio, there is an optimum diffuser length which will result in maximum pressure recovery. This point is illustrated further in Figure 18. Figure 18 shows diffuser performance as a function of area ratio for various values of the length ratio and an inlet Mach number of 0.70. It can be seen that at low values of area ratio the curves coincide. As the area ratio increases, the curves for the lower values of length ratio drop off. From this plot, one can readily determine the optimum length ratio for maximum performance at a given area ratio. For example, for an area ratio = 1.70 and Mach number = 0.70, Figure 18 indicates that no increase in performance is to be gained by going to an N/R_1 above 8.0.

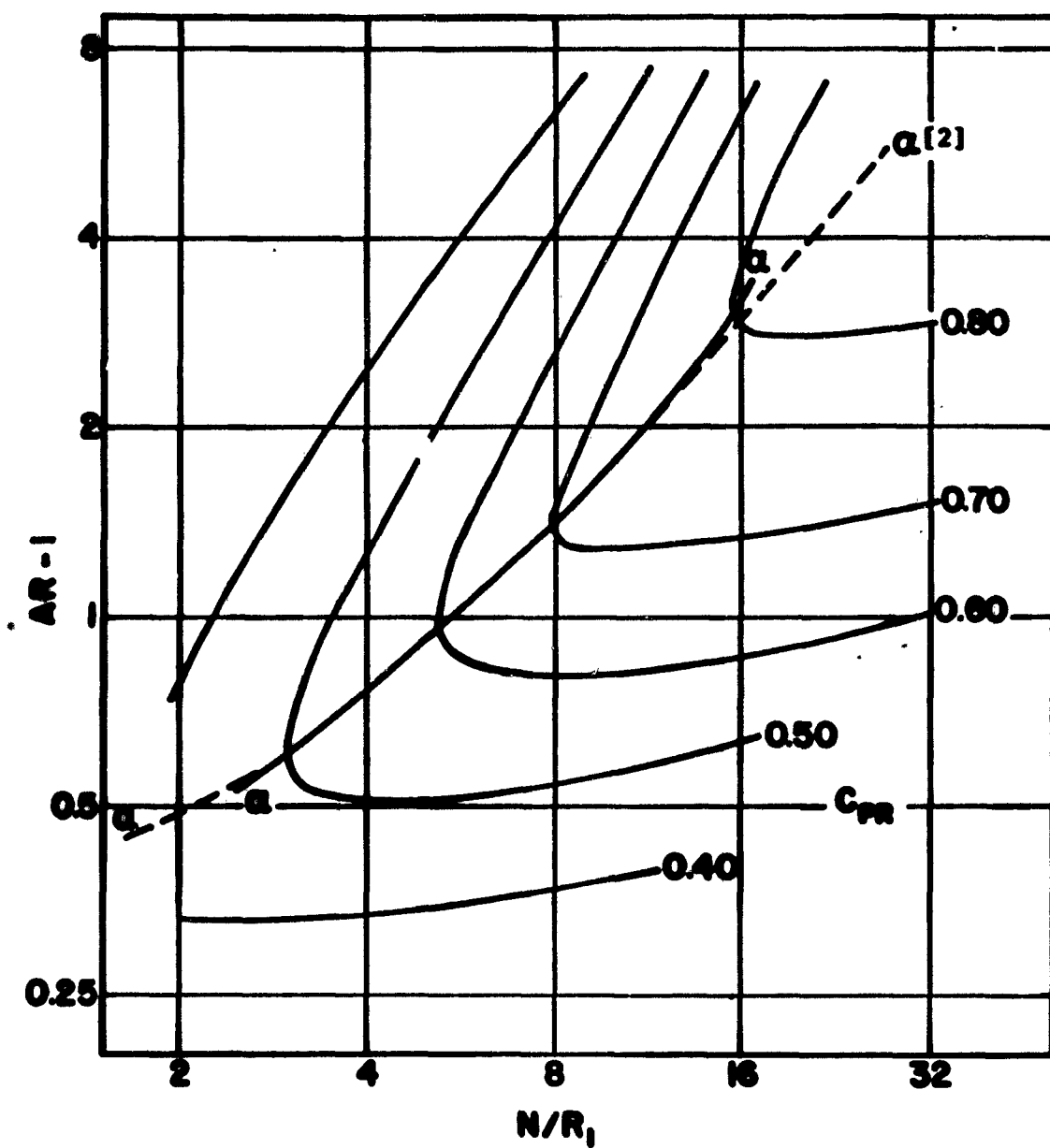


Figure 15. Performance Map for Conical Diffusers with $M_1=0.25$

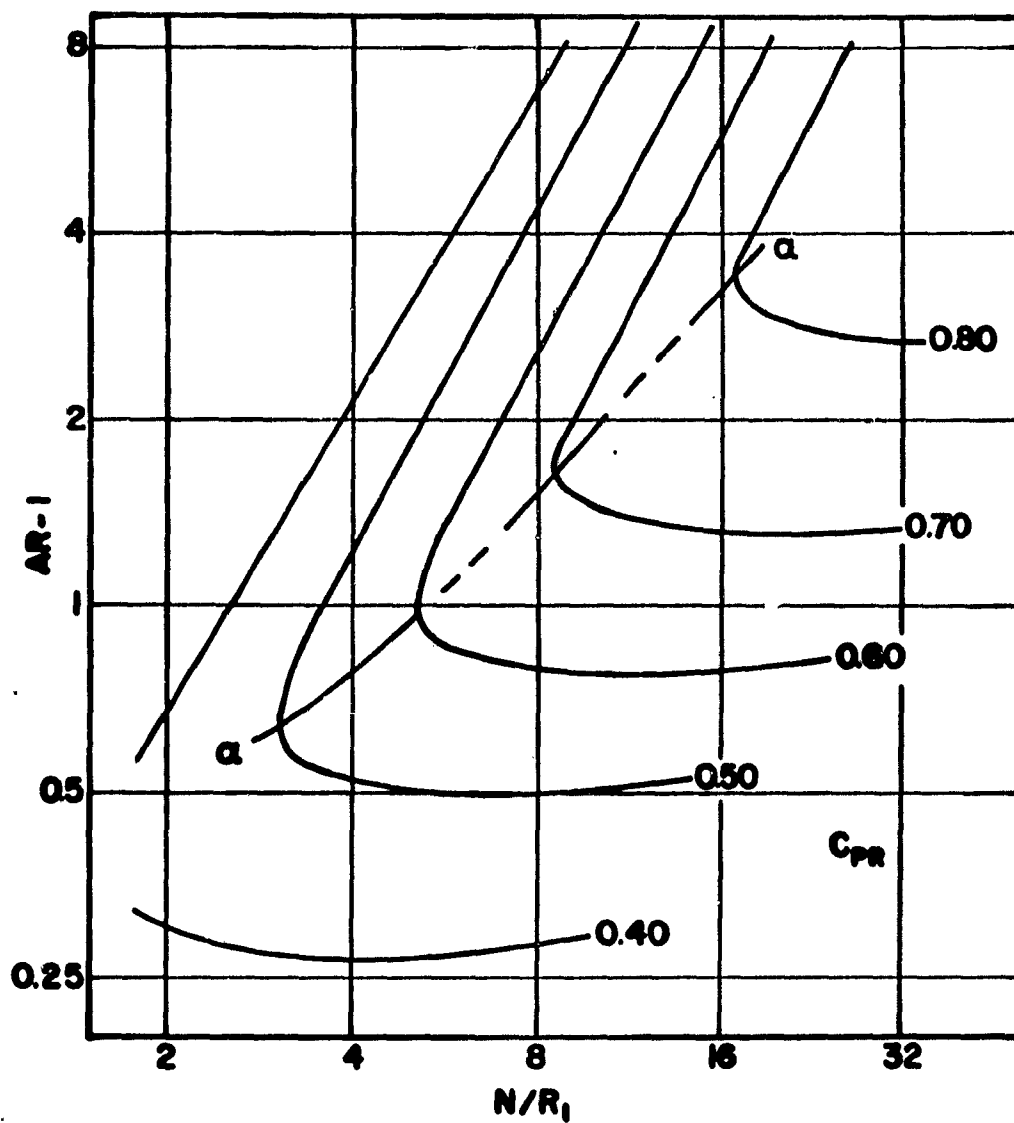


Figure 16. Performance Map for Conical Diffusers with $M_1 = 0.55$

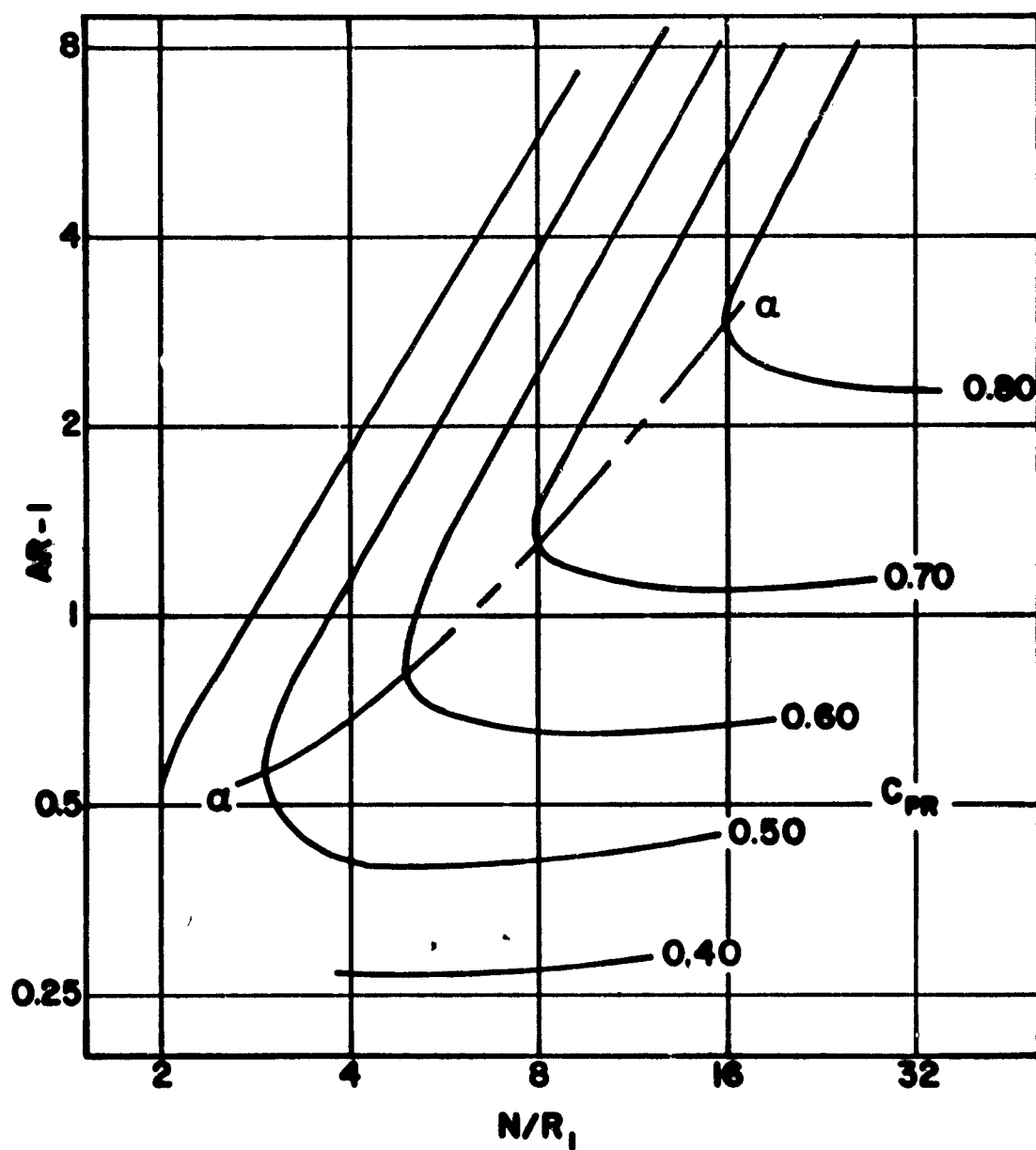


Figure 17. Performance Map for Conical Diffusers with $M_1 = 0.70$

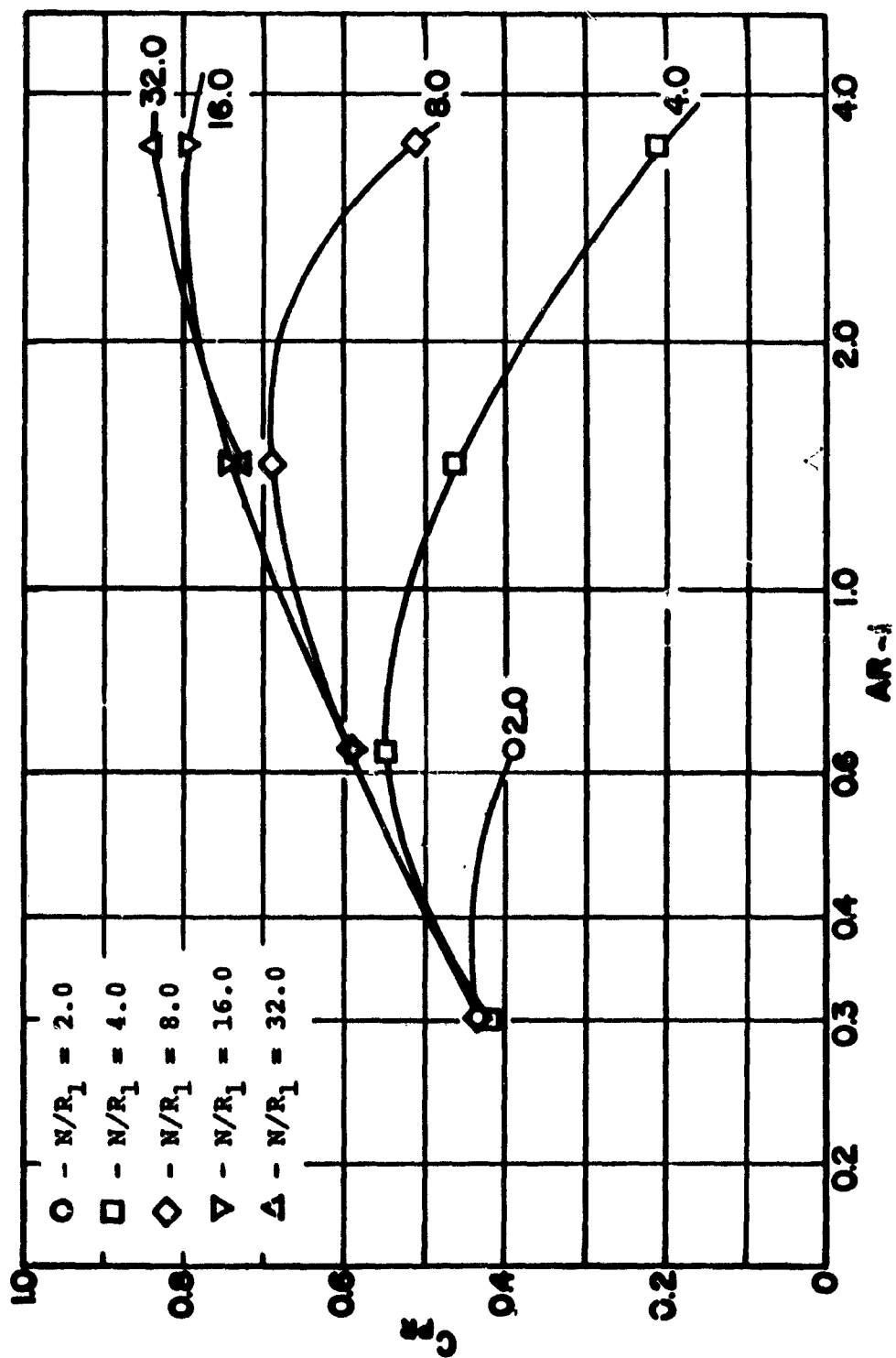


Figure 18. Diffuser Performance vs AR for Constant N/R_1 at $M_1 = 0.70$

CONCLUSIONS

From a consideration of the foregoing experimental results, the following conclusions can be drawn:

1. For incompressible flow the line of first appreciable stall, line a-a, is essentially that found by McDonald and Fox². As the Mach number is increased, however, the flow tends more toward separation in all cases.
2. The variation of the diffuser performance with inlet Mach number appears to correlate on the location of line a-a for incompressible flow.
 - For diffuser geometries lying below line a-a there is a slight increase in diffuser performance with increasing Mach number.
 - For diffuser geometries lying close to line a-a diffuser performance is essentially constant up to the point of local choking.
 - For diffuser geometries lying above the line a-a diffuser performance decreases with increasing Mach number.
3. At a given area ratio, diffuser performance, for a given Mach number, is independent of diffuser divergence angle (or length ratio) for diffuser geometries lying below the line of first appreciable stall. For a given area ratio, diffuser performance will drop off at all Mach numbers as one proceeds to geometries

lying above line a-a. The drop off in performance increases with increasing distance above the line a-a.

4. For a given divergence angle, diffuser performance at any Mach number is maximum for the maximum area ratio. The spread in performance as a function of area ratio for a given divergence angle decreases as the divergence angle is increased. At a divergence angle of 31.2 degrees, diffuser performance is uniformly low and independent of area ratio at all Mach numbers.
5. There is no significant variation in the location of the line of maximum performance at constant length to inlet radius ratio, line a-a, with inlet Mach number. For $M_1 = 0.25$ line a-a of the present study is virtually identical to that found in the earlier water flow studies of McDonald and Fox².
6. For a given area ratio and inlet Mach number there is an optimum length beyond which no increase in diffuser performance is obtained.

REFERENCES

1. Kline, S.J., Abbott, D.E., and Fox, R.W., "Optimum Design of Straight Wall Diffusers," Transactions of ASME, Journal of Basic Engineering, vol. 81, September 1959.
2. McDonald, A.T., and Fox, R.W., "Incompressible Flow in Conical Diffusers," Purdue Research Foundation, Report no. 1, September 1964.
3. Ackeret, J., "High Speed Wind Tunnels," NACA TM 808, 1936.
4. Copp, M.R., "Effects of Inlet Wall Contour on the Pressure Recovery of a 10 Degree, 10 Inch Inlet-Diameter Conical Diffuser," NACA RM L51F11a, 1951.
5. Little, E.F. and Wilbur, J.S., "Performance and Boundary-Layer Data from 12 and 23 Degree Diffusers of Area Ratio 2.0 at Mach numbers up to Choking and Reynolds numbers to 7.5×10^6 ," NACA Report 1201, 1954.
6. Naumann, A., "Diffuser Efficiencies at High Subsonic Velocities," Technical Institute for Aeronautics, Aachen, Rep. no. FB 1705, March 30, 1943. (Deutsche Luftfahrtforschung, Berlin-Aldershof, 1942).
7. Scherrer, R. and Anderson, W.E., "Preliminary Investigation of a Family of Diffusers Designed for near Sonic Inlet Velocities," NACA TN 3668, 1956.
8. Smith, R.H. and Wang, Chi-Teh, "Contracting Cones Giving Uniform Throat Speeds," Journal of the Aeronautical Sciences, vol. 11, no. 4, October 1944.

APPENDIX A
Data and Calculated Performance Parameters for
Current Investigation

Table A1. $2\phi = 2.0$ degrees $N/R_1 = 8.0$ $AR = 1.30$

M_1	q_1 psf	ReD_1 $\times 10^5$	P_0 psi	P_1 psi	Local Cpr $X(in)$			Diffuser	
					1.5	3.5	5.5	7.5	η CPR
0.25	88.	0.24	14.91	14.30	0.08	0.12	0.20	0.24	0.32 0.75
0.26	95.	0.25	14.98	14.32	0.07	0.11	0.15	0.19	0.26 0.61
0.30	134.	0.30	15.11	14.17	0.05	0.08	0.24	0.29	0.34 0.78
0.43	273.	0.42	15.74	13.83	0.05	0.12	0.21	0.28	0.35 0.79
0.53	405.	0.51	16.36	13.51	0.05	0.11	0.19	0.29	0.35 0.75
0.54	418.	0.52	16.38	13.44	0.05	0.13	0.21	0.30	0.36 0.78
0.62	537.	0.58	16.85	13.04	0.05	0.14	0.24	0.32	0.39 0.79
0.67	632.	0.63	17.19	12.70	0.06	0.16	0.25	0.34	0.41 0.83
0.70	682.	0.65	17.34	12.48	0.07	0.17	0.27	0.36	0.43 0.85
0.74	748.	0.68	17.51	12.16	0.08	0.19	0.29	0.38	0.45 0.87
0.76	778.	0.69	17.59	12.01	0.08	0.20	0.31	0.40	0.46 0.88
0.76	791.	0.70	17.86	12.18	0.07	0.17	0.26	0.35	0.42 0.80
0.79	847.	0.72	18.05	11.96	0.08	0.18	0.28	0.37	0.43 0.81
0.83	922.	0.74	18.32	11.67	0.08	0.19	0.29	0.38	0.44 0.80
0.85	963.	0.76	18.45	11.47	0.08	0.21	0.30	0.39	0.45 0.81

Table A2. $2\phi = 2.0$ degrees $M/R_1 = 16.0$ $AR = 1.64$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{PR} $X(in)$					Diffuser	
	psf	$\times 10^5$	psi	psi	1.5	3.5	5.5	7.5	11.5	C_{PR}	η
0.22	71.	0.21	14.76	14.27	0.05	0.15	0.15	0.25	0.35	0.50	0.79
0.30	134.	0.29	14.98	14.05	0.05	0.11	0.18	0.26	0.37	0.50	0.78
0.37	193.	0.35	15.18	13.83	0.05	0.11	0.20	0.27	0.40	0.51	0.78
0.41	242.	0.39	15.33	13.63	0.04	0.12	0.19	0.29	0.42	0.53	0.79
0.47	311.	0.44	15.55	13.36	0.05	0.11	0.20	0.30	0.44	0.53	0.80
0.53	387.	0.49	15.77	13.04	0.05	0.12	0.20	0.29	0.44	0.55	0.81
0.59	469.	0.54	16.01	12.70	0.05	0.13	0.21	0.30	0.45	0.56	0.81
0.67	597.	0.60	16.36	12.11	0.05	0.15	0.24	0.33	0.49	0.58	0.82
0.74	707.	0.64	16.63	11.57	0.07	0.17	0.26	0.35	0.50	0.60	0.83
0.81	818.	0.68	16.85	10.95	0.08	0.19	0.29	0.38	0.56	0.63	0.84
0.87	897.	0.69	16.70	10.19	0.06	0.23	0.34	0.44	0.60	0.69	0.91

Table A3. $2\phi = 2.0$ degrees $N/R_1 = 32.0$ $AR = 2.43$

M ₁	q ₁	Re _{D₁}	P _O	P ₁	Local C _{pr}								Diffuser				
					psi	psi	1.5	3.5	5.5	9.5	15.5	17.5	21.5	25.5	29.5	C _{pr}	η
	psf	x10 ⁵															
0.22	67	0.21	14.66	14.20	0.05	0.11	0.16	0.32	0.47	0.53	0.79	0.65	0.67	0.68	0.82		
0.33	151.	0.31	14.86	13.80	0.05	0.12	0.16	0.33	0.44	0.49	0.61	0.65	0.67	0.68	0.80		
0.42	249.	0.39	15.06	13.31	0.04	0.11	0.18	0.36	0.47	0.53	0.61	0.64	0.67	0.70	0.82		
0.53	380.	0.48	15.33	12.65	0.05	0.12	0.20	0.37	0.49	0.53	0.61	0.65	0.69	0.71	0.82		
0.61	489.	0.54	15.52	12.06	0.04	0.14	0.22	0.39	0.51	0.56	0.63	0.67	0.70	0.72	0.82		
0.69	603.	0.59	15.74	11.45	0.05	0.15	0.24	0.41	0.53	0.57	0.65	0.68	0.71	0.73	0.82		
0.78	732.	0.63	15.97	10.71	0.06	0.17	0.27	0.44	0.56	0.60	0.66	0.70	0.73	0.75	0.82		
0.84	825.	0.66	16.06	10.10	0.08	0.20	0.30	0.47	0.59	0.63	0.68	0.72	0.75	0.77	0.84		
0.87	860.	0.67	16.16	9.92	0.08	0.21	0.31	0.48	0.60	0.63	0.69	0.72	0.75	0.77	0.83		

Table A4. $2\phi = 4.0$ degrees $N/R_1 = 4.0$ $AR = 1.30$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{PR} $X(in)$	Diffuser
	psf	$\times 10^5$	psi	psi	1.5	3.5 C_{PR} n
0.21	67.	0.21	14.81	14.34	0.16	0.32 0.37 0.88
0.28	113.	0.27	15.01	14.22	0.16	0.31 0.38 0.87
0.35	176.	0.34	15.28	14.05	0.16	0.32 0.38 0.89
0.41	242.	0.40	15.57	13.88	0.15	0.32 0.38 0.86
0.47	312.	0.45	15.87	13.68	0.16	0.34 0.39 0.86
0.56	439.	0.53	16.38	13.29	0.17	0.35 0.40 0.86
0.61	527.	0.58	16.75	13.02	0.18	0.36 0.41 0.84
0.69	659.	0.64	17.27	12.58	0.18	0.37 0.42 0.85
0.75	761.	0.68	17.56	12.11	0.21	0.40 0.46 0.88
0.78	817.	0.70	17.71	11.84	0.23	0.42 0.47 0.89
0.81	866.	0.72	17.86	11.62	0.24	0.43 0.48 0.89

Table A5. $2\theta = 4.0$ degrees $M/R_1 = 8.0$ $AR = 1.64$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{PR} $x(in)$					Diffuser
	psf	$x10^5$	psi	psi	1.5	3.5	5.5	7.5	C_{PR}	n
0.49	332	0.46	15.60	13.26	0.14	0.32	0.43	0.50	0.54	0.81
0.54	401	0.50	15.82	12.99	0.13	0.32	0.62	0.51	0.55	0.81
0.60	483	0.54	16.04	12.62	0.15	0.34	0.45	0.53	0.56	0.82
0.66	577	0.59	16.31	12.21	0.15	0.35	0.47	0.54	0.58	0.82
0.72	674	0.63	16.58	11.77	0.16	0.36	0.48	0.56	0.59	0.82
0.77	760	0.66	16.78	11.32	0.18	0.38	0.50	0.57	0.61	0.82
0.82	834	0.69	16.97	10.95	0.20	0.40	0.50	0.58	0.61	0.82
0.89	949	0.72	17.22	10.32	0.23	0.42	0.53	0.61	0.64	0.83
0.90	995	0.74	17.61	10.37	0.12	0.36	0.49	0.57	0.60	0.77
0.90	998	0.74	17.73	10.46	0.03	0.32	0.46	0.55	0.58	0.75
0.91	991	0.73	17.49	10.27	0.16	0.38	0.51	0.59	0.62	0.79

Table A6. $2\phi = 4.0$ degrees $M/R_1 = 16.0$ $AR = 2.43$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{PR}			Diffuser	
	$psf \times 10^5$		psi	psi	1.5	3.5	5.5	7.5	11.5
									n
0.48	315	0.44	15.28	13.07	0.15	0.33	0.43	0.46	0.65
0.59	455	0.52	15.52	12.31	0.16	0.34	0.46	0.60	0.68
0.70	617	0.59	15.82	11.42	0.17	0.37	0.48	0.63	0.71
0.74	686	0.62	15.97	11.05	0.18	0.38	0.48	0.62	0.71
0.81	790	0.65	16.16	10.46	0.21	0.40	0.51	0.64	0.72
0.85	842	0.67	16.26	10.17	0.22	0.41	0.51	0.65	0.72
0.92	959	0.70	16.53	9.53	0.21	0.42	0.52	0.66	0.73
0.92	979	0.71	16.95	9.80	0.02	0.31	0.44	0.60	0.67
0.93	1001	0.72	17.05	9.73	0.05	0.31	0.45	0.59	0.67

Table A7. $2\theta = 4.0$ degrees $N/R_1 = 32.0$ $AR = 4.48$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{Pr}										Diffuser	
					psi	1.5	3.5	5.5	9.5	13.5	17.5	21.5	25.5	29.5	C_{Pr}	η
	psf $\times 10^5$		psi	psi												
0.26	95	0.25	14.66	14.00	0.15	0.33	0.45	0.56	0.71	0.82	0.78	0.82	0.82	0.82	0.85	0.89
0.35	169	0.33	14.76	13.58	0.15	0.34	0.42	0.59	0.67	0.73	0.80	0.82	0.82	0.82	0.84	0.87
0.45	273	0.41	14.91	12.99	0.16	0.34	0.43	0.53	0.66	0.72	0.79	0.82	0.82	0.82	0.83	0.86
0.56	407	0.49	15.08	12.21	0.16	0.36	0.45	0.60	0.69	0.74	0.79	0.82	0.82	0.82	0.83	0.86
0.68	569	0.56	15.28	11.22	0.18	0.38	0.48	0.63	0.71	0.76	0.81	0.83	0.84	0.84	0.84	0.86
0.76	688	0.61	15.47	10.54	0.20	0.40	0.49	0.64	0.71	0.76	0.80	0.82	0.83	0.84	0.84	0.85
0.89	865	0.65	15.72	9.43	0.23	0.43	0.53	0.66	0.73	0.78	0.82	0.84	0.85	0.85	0.85	0.84
0.90	897	0.67	15.92	9.38	0.17	0.39	0.50	0.64	0.71	0.76	0.80	0.82	0.82	0.82	0.83	0.82
0.91	920	0.68	16.24	9.53	0.07	0.33	0.45	0.60	0.67	0.71	0.75	0.77	0.78	0.79	0.79	0.78

Table A8. $2\phi = 8.0$ degrees $M/R_1 = 2.0$ $AR = 1.30$

M_1	q_1	Re_{D_1}	P_0	P_1	C_{PR}	Diffuser
	psf	$\times 10^5$	psi	psi	1.5 C_{PR}	η
0.21	67.	0.21	14.86	14.39	0.32	0.37 0.88
0.29	127.	0.29	15.11	14.22	0.31	0.39 0.89
0.36	190.	0.35	15.40	14.07	0.32	0.39 0.91
0.42	260.	0.41	15.72	13.90	0.31	0.38 0.86
0.47	322.	0.46	15.97	13.71	0.32	0.38 0.85
0.52	391.	0.50	16.26	13.51	0.37	0.40 0.86
0.57	459.	0.54	16.53	13.29	0.34	0.40 0.84
0.61	534.	0.58	16.85	13.07	0.34	0.40 0.83
0.65	602.	0.62	17.10	12.82	0.36	0.42 0.85
0.69	665.	0.64	17.34	12.60	0.37	0.43 0.85
0.72	709.	0.66	17.49	12.43	0.38	0.43 0.86
0.74	755.	0.68	17.66	12.26	0.39	0.44 0.85

Table A9. $2\phi = 8.0$ degrees $N/R_1 = 4.0$ $AR = 1.64$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{pR}			Diffuser
					$X(in)$	1.5	3.5	
	psf $\times 10^5$	psi	psi	psi			η	
0.21	67	0.21	14.79	14.32	0.32	0.47	0.58	0.92
0.28	116	0.28	14.98	14.17	0.30	0.46	0.52	0.80
0.34	165	0.33	15.15	14.00	0.32	0.47	0.51	0.79
0.38	204	0.36	15.28	13.85	0.31	0.49	0.52	0.79
0.42	256	0.41	15.45	13.66	0.32	0.48	0.52	0.78
0.46	305	0.44	15.60	13.46	0.33	0.49	0.53	0.80
0.52	384	0.49	15.87	13.17	0.32	0.50	0.53	0.79
0.59	476	0.54	16.14	12.77	0.34	0.51	0.54	0.79
0.63	547	0.58	16.38	12.50	0.35	0.51	0.54	0.78
0.69	641	0.62	16.70	12.13	0.36	0.52	0.55	0.77
0.74	717	0.65	16.92	11.79	0.36	0.53	0.56	0.77
0.80	822	0.69	17.24	11.32	0.38	0.54	0.57	0.76
0.81	828	0.68	17.00	11.03	0.42	0.58	0.61	0.82
0.82	848	0.70	17.29	11.18	0.39	0.54	0.56	0.77
0.85	916	0.72	17.51	10.88	0.40	0.55	0.58	0.76
0.88	957	0.73	17.66	10.71	0.40	0.55	0.58	0.76
0.89	977	0.74	17.78	10.68	0.38	0.54	0.57	0.74

Table A10. $2\phi = 8.0$ degrees $M/R_1 = 8.0$ $AR = 2.43$

M_1	q_1	Re_{D_1}	P_0	P_1		Local C_{Pr}				Diffuser	
				psi	psi	1.5	3.5	5.5	7.5		C_{Pr}
	psf $\times 10^5$		psi	psi							
0.22	71	0.21	14.71	14.22	0.30	0.30	0.50	0.55	0.65	0.70	0.84
0.30	127	0.29	14.84	13.95	0.31	0.31	0.47	0.61	0.67	0.70	0.83
0.36	183	0.34	14.98	13.71	0.31	0.31	0.48	0.59	0.65	0.68	0.80
0.43	256	0.40	15.13	13.34	0.33	0.33	0.50	0.62	0.67	0.69	0.81
0.51	353	0.47	15.35	12.87	0.33	0.33	0.50	0.61	0.67	0.69	0.80
0.57	438	0.51	15.55	12.45	0.34	0.34	0.50	0.61	0.69	0.69	0.80
0.64	530	0.56	15.77	12.01	0.35	0.35	0.51	0.61	0.67	0.69	0.79
0.71	647	0.61	16.06	11.45	0.36	0.36	0.51	0.61	0.68	0.69	0.77
0.78	749	0.65	16.33	10.95	0.37	0.37	0.51	0.61	0.68	0.69	0.76
0.83	840	0.67	16.58	10.51	0.38	0.38	0.52	0.62	0.68	0.69	0.76
0.88	923	0.70	16.83	10.12	0.38	0.38	0.51	0.61	0.67	0.69	0.75
0.90	992	0.74	17.61	10.39	0.19	0.19	0.37	0.51	0.58	0.61	0.65
0.90	995	0.74	17.78	10.54	0.12	0.12	0.33	0.48	0.56	0.58	0.63
0.90	996	0.75	17.86	10.61	0.10	0.10	0.31	0.47	0.55	0.57	0.62
0.91	967	0.72	17.07	10.02	0.36	0.36	0.49	0.60	0.66	0.68	0.73
0.91	987	0.73	17.34	10.14	0.30	0.30	0.44	0.56	0.63	0.64	0.69

Table All. $2\phi = 8.0$ degrees $M/R_1 = 16.0$ $AR = 4.48$

M_1	q_1	Re_{D_1}	P_0	P_1	Local C _{pr} x(in)					Diffuser	
	psf x10 ⁵	psi	psi	psi	1.5	3.5	5.5	7.5	11.5	C _{pr}	n
0.23	78	0.22	14.66	14.12	0.32	0.50	0.64	0.68	0.77	0.32	0.86
0.34	162	0.32	14.81	13.68	0.31	0.48	0.61	0.68	0.74	0.79	0.82
0.42	246	0.39	14.93	13.21	0.33	0.49	0.58	0.65	0.72	0.79	0.82
0.52	363	0.47	15.13	12.58	0.34	0.50	0.59	0.66	0.73	0.79	0.81
0.64	526	0.55	15.40	11.67	0.36	0.50	0.61	0.68	0.75	0.79	0.81
0.71	620	0.59	15.60	11.18	0.37	0.51	0.61	0.67	0.74	0.79	0.80
0.79	745	0.63	15.87	10.51	0.38	0.51	0.61	0.67	0.74	0.78	0.78
0.85	838	0.66	16.09	10.02	0.38	0.51	0.61	0.67	0.73	0.78	0.77
0.91	927	0.69	16.41	9.65	0.36	0.49	0.59	0.65	0.72	0.76	0.75
0.91	953	0.70	16.73	9.78	0.29	0.43	0.54	0.60	0.67	0.72	0.71
0.91	964	0.71	16.95	9.92	0.22	0.37	0.50	0.57	0.64	0.69	0.68
0.91	977	0.72	17.19	10.07	0.11	0.30	0.45	0.53	0.62	0.66	0.65

Table A12. $2\phi = 8.0$ degrees $N/R_1 = 26.8$ $AR = 8.27$

M ₁	q ₁	Re _{D₁}	P _O	P ₁	Local Cpr										Diffuser		
					psi	psi	1.5	3.5	5.5	7.5	11.5	15.5	19.5	23.5		27.5	Cpr
	psf x10 ⁵		psi	psi													
0.26	99	0.25	14.66	13.98	0.32	0.50	0.61	0.68	0.79	0.82	0.86	0.86	0.86	0.86	0.86	0.86	0.87
0.35	169	0.33	14.76	13.58	0.34	0.50	0.61	0.67	0.75	0.80	0.83	0.84	0.84	0.84	0.84	0.84	0.84
0.43	256	0.40	14.86	13.07	0.36	0.50	0.61	0.68	0.75	0.79	0.83	0.84	0.84	0.84	0.84	0.84	0.85
0.50	332	0.45	14.98	12.65	0.34	0.49	0.60	0.67	0.75	0.79	0.82	0.83	0.83	0.83	0.83	0.83	0.83
0.56	404	0.49	15.08	12.23	0.36	0.50	0.60	0.67	0.74	0.79	0.82	0.83	0.83	0.83	0.83	0.83	0.83
0.62	485	0.53	15.20	11.77	0.36	0.50	0.61	0.68	0.74	0.79	0.82	0.83	0.83	0.83	0.83	0.83	0.82
0.68	579	0.57	15.35	11.22	0.37	0.51	0.61	0.67	0.74	0.78	0.82	0.83	0.83	0.83	0.83	0.83	0.82
0.79	734	0.62	15.67	10.39	0.39	0.51	0.60	0.67	0.74	0.77	0.81	0.82	0.82	0.82	0.82	0.82	0.80
0.79	734	0.62	15.67	10.39	0.39	0.51	0.60	0.67	0.74	0.77	0.80	0.81	0.82	0.82	0.82	0.82	0.80
0.86	841	0.65	15.89	9.80	0.40	0.51	0.61	0.67	0.74	0.77	0.80	0.81	0.82	0.82	0.82	0.82	0.79
0.91	924	0.68	16.28	9.55	0.34	0.46	0.57	0.63	0.70	0.74	0.75	0.77	0.78	0.78	0.78	0.78	0.75
0.91	960	0.71	16.87	9.87	0.17	0.33	0.47	0.55	0.62	0.66	0.69	0.70	0.70	0.70	0.70	0.70	0.68
0.91	984	0.73	17.39	10.22	0.03	0.22	0.38	0.46	0.55	0.59	0.62	0.63	0.64	0.64	0.64	0.64	0.61

Table A13. $2\phi = 15.8$ degrees $N/R_1 = 2.0$ $AR = 1.64$

M_1	q_1	Re_{D_1}	P_0	P_1	C_{PR}	Diffuser
		$\text{psf} \times 10^5$	psi	psi	$X(\text{in})$	n
0.22	67	0.33	14.74	14.27	0.37	0.47 0.83
0.31	137	0.47	15.03	14.07	0.39	0.44 0.72
0.38	207	0.58	15.35	13.90	0.36	0.41 0.65
0.42	256	0.65	15.57	13.78	0.36	0.40 0.62
0.47	315	0.71	15.84	13.63	0.35	0.39 0.61
0.52	391	0.79	16.14	13.39	0.36	0.41 0.62
0.58	469	0.87	16.53	13.21	0.35	0.39 0.58
0.62	537	0.93	16.83	13.02	0.36	0.39 0.58
0.68	645	0.10	17.29	12.70	0.36	0.39 0.57
0.72	712	0.11	17.61	12.53	0.36	0.39 0.56
0.74	752	0.11	17.81	12.43	0.36	0.39 0.55

Table A14. $2\phi = 15.8$ degrees $M/R_1 = 4.0$ $AR = 2.43$

M_1	q_1	Re_{D_1}	P_0	P_1	Local Cpr $X(in)$	Diffuser
	psf $\times 10^5$	psi	psi	1.5	3.5	C_{PR} η
0.26	95	0.25	14.86	14.20	0.33	0.45 0.48 0.58
0.31	141	0.30	15.01	14.02	0.35	0.48 0.50 0.60
0.38	211	0.37	15.30	13.83	0.34	0.44 0.47 0.56
0.43	263	0.41	15.47	13.63	0.34	0.44 0.48 0.57
0.47	318	0.45	15.70	13.46	0.33	0.43 0.48 0.56
0.54	404	0.51	16.01	13.17	0.31	0.45 0.48 0.55
0.59	486	0.55	16.36	12.92	0.33	0.44 0.47 0.54
0.64	571	0.60	16.73	12.67	0.33	0.42 0.46 0.53
0.69	658	0.64	17.12	12.43	0.31	0.41 0.46 0.51
0.74	745	0.67	17.46	12.13	0.32	0.42 0.46 0.51
0.77	791	0.69	17.64	11.96	0.28	0.41 0.47 0.51
0.78	820	0.70	17.81	11.91	0.26	0.41 0.46 0.50
0.78	824	0.71	17.86	11.94	0.24	0.40 0.45 0.50

Table A15. $2\theta = 15.8$ degrees $M/R_1 = 9.0$ $AR = 4.48$

M_1	q_1	Re_{D_1}	P_0	P_1	Local C_{PR} $x(in)$			Diffuser	
		$pef \times 10^5$	psi	psi	1.5	3.5	5.5	7.5	C_{PR} n
0.25	88	0.24	14.84	14.22	0.28	0.40	0.44	0.48	0.52 0.55
0.40	225	0.38	15.25	13.68	0.31	0.41	0.47	0.52	0.55 0.57
0.45	291	0.43	15.47	13.44	0.33	0.40	0.47	0.51	0.55 0.57
0.53	387	0.49	15.84	13.12	0.31	0.38	0.45	0.49	0.53 0.55
0.68	631	0.62	16.75	12.26	0.30	0.37	0.44	0.49	0.52 0.53
0.73	716	0.66	17.17	12.05	0.29	0.35	0.42	0.47	0.50 0.51
0.77	784	0.69	17.46	11.84	0.28	0.35	0.42	0.47	0.50 0.50
0.79	833	0.70	17.68	11.69	0.28	0.35	0.41	0.46	0.49 0.49
0.81	869	0.72	17.83	11.57	0.26	0.34	0.41	0.46	0.49 0.49
0.82	885	0.72	17.93	11.54	0.25	0.32	0.40	0.46	0.49 0.49
0.83	918	0.74	18.13	11.50	0.24	0.32	0.39	0.44	0.48 0.48
0.84	931	0.74	18.13	11.40	0.24	0.32	0.48	0.53	0.49 0.48

Table A16. $2\phi = 15.8$ degrees $N/R_1 = 13.4$ $AR = 8.27$

M_1	q_1	Re_{D_1}	P_0	P_1	Local C_{PR}					C_{PR}	η	Diffuser
					$x(in)$	1.5	3.5	7.5	9.5			
		psf $\times 10^5$	psi	psi								
0.22	71	0.21	14.79	14.30	0.35	0.45	0.60	0.60	0.60	0.60	0.60	0.61
0.29	120	0.28	14.93	14.10	0.32	0.44	0.56	0.59	0.59	0.59	0.59	0.60
0.37	197	0.36	15.18	13.80	0.32	0.41	0.50	0.56	0.56	0.56	0.57	0.58
0.46	294	0.43	15.45	13.39	0.32	0.42	0.49	0.55	0.57	0.57	0.59	0.59
0.54	404	0.50	15.82	12.97	0.32	0.40	0.47	0.53	0.55	0.58	0.58	0.58
0.65	567	0.59	16.38	12.35	0.32	0.39	0.46	0.52	0.54	0.57	0.56	0.56
0.71	674	0.64	16.80	11.99	0.30	0.37	0.45	0.51	0.53	0.56	0.55	0.55
0.77	783	0.68	17.27	11.64	0.29	0.36	0.43	0.50	0.52	0.54	0.53	0.53
0.83	894	0.72	17.66	11.20	0.28	0.35	0.43	0.50	0.52	0.55	0.55	0.53
0.86	949	0.74	17.95	11.08	0.25	0.33	0.41	0.48	0.51	0.53	0.52	0.52

Table A17. $2\phi = 31.2$ degrees $M/R_1 = 2.0$ $AR = 2.43$

M_1	q_1	Re_{D_1}	P_o	P_1	C_{PR}	Diffuser
	$psf \times 10^5$		psi	psi	$X(in)$	η
0.20	60	0.32	14.91	14.49	0.29	0.35 0.42
0.29	120	0.45	15.23	14.39	0.24	0.30 0.35
0.34	165	0.53	15.45	14.30	0.15	0.30 0.35
0.37	200	0.58	15.67	14.27	0.04	0.25 0.31
0.40	242	0.64	15.94	14.25	0.04	0.22 0.27
0.44	284	0.69	16.24	14.25	0.04	0.19 0.23
0.49	360	0.78	16.65	14.12	0.12	0.20 0.24
0.55	453	0.87	17.12	13.93	0.18	0.22 0.26
0.60	538	0.95	17.61	13.80	0.18	0.22 0.25
0.63	592	1.00	17.95	13.75	0.16	0.21 0.24
0.64	609	1.00	18.08	13.75	0.16	0.20 0.24
0.65	626	1.00	18.15	13.71	0.16	0.20 0.24
0.65	636	1.00	18.20	13.68	0.16	0.21 0.24

Table A18. $2\phi = 31.2$ degrees $N/R_1 = 4.0$ $AR = 4.48$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{PR}			Diffuser
					$X(in)$	1.5	3.5	
	psf $\times 10^5$	psi	psi	psi			C_{PR}	n
0.23	78	0.23	14.86	14.32	0.23	0.27	0.27	0.33
0.27	102	0.26	14.96	14.25	0.24	0.28	0.35	0.36
0.33	162	0.33	15.28	14.15	0.24	0.26	0.31	0.32
0.38	207	0.37	15.52	14.07	0.22	0.24	0.29	0.30
0.43	273	0.42	15.89	13.98	0.19	0.22	0.27	0.28
0.46	305	0.45	16.04	13.90	0.19	0.21	0.28	0.29
0.48	332	0.47	16.21	13.88	0.15	0.17	0.27	0.28
0.50	363	0.49	16.43	13.88	0.12	0.15	0.24	0.25
0.55	436	0.53	16.75	13.68	0.15	0.19	0.27	0.28
0.55	449	0.55	16.92	13.75	0.13	0.17	0.23	0.24
0.59	500	0.57	17.10	13.56	0.17	0.20	0.26	0.28
0.61	548	0.60	17.39	13.51	0.16	0.19	0.25	0.26
0.64	595	0.63	17.64	13.41	0.17	0.20	0.26	0.27
0.64	599	0.63	17.81	13.56	0.14	0.18	0.21	0.23
0.65	626	0.64	17.83	13.39	0.05	0.20	0.25	0.26
0.67	666	0.66	18.15	13.41	0.14	0.18	0.22	0.24
0.69	707	0.69	18.42	13.39	0.14	0.17	0.22	0.23
0.70	727	0.70	18.54	13.36	0.14	0.18	0.21	0.23

Table A19. $2\phi = 31.2$ degrees $N/R_1 = 6.7$ $AR = 8.27$

M_1	q_1	Re_{D_1}	P_o	P_1	Local C_{PR} $X(in)$	Diffuser
	psf $\times 10^5$	psi	psi	1.5	3.5	5.5 C_{PR} n
0.19	53	0.19	14.71	14.34	0.27	0.33 0.40 0.41
0.23	78	0.23	14.86	14.32	0.23	0.27 0.32 0.32
0.30	127	0.29	15.08	14.20	0.25	0.28 0.31 0.33 0.34
0.31	144	0.31	15.20	14.20	0.22	0.24 0.29 0.30
0.34	165	0.33	15.30	14.15	0.24	0.26 0.30 0.30
0.38	207	0.37	15.50	14.05	0.22	0.24 0.27 0.31 0.31
0.43	267	0.42	15.84	13.98	0.27	0.21 0.23 0.28 0.28
0.45	294	0.44	15.99	13.93	0.20	0.22 0.23 0.28 0.28
0.48	336	0.47	16.19	13.83	0.20	0.21 0.24 0.28 0.28
0.49	356	0.48	16.36	13.85	0.16	0.19 0.23 0.26 0.26
0.54	418	0.52	16.63	13.68	0.19	0.21 0.25 0.28 0.28
0.57	473	0.56	16.92	13.58	0.19	0.20 0.24 0.28 0.28
0.59	514	0.58	17.14	13.51	0.19	0.20 0.24 0.28 0.27
0.62	551	0.60	17.32	13.41	0.19	0.21 0.25 0.28 0.28
0.62	568	0.61	17.46	13.44	0.18	0.19 0.22 0.27 0.27
0.64	609	0.63	17.81	13.48	0.14	0.16 0.21 0.24 0.24
0.68	683	0.67	18.23	13.36	0.14	0.16 0.21 0.24 0.23
0.70	713	0.69	18.45	13.36	0.13	0.15 0.20 0.23 0.22
0.70	730	0.70	18.52	13.31	0.14	0.16 0.20 0.23 0.23

APPENDIX F

**Tabulation of Diffuser Performance at Selected Mach Numbers
and Cross Plots of Data Used in Plotting Performance Maps**

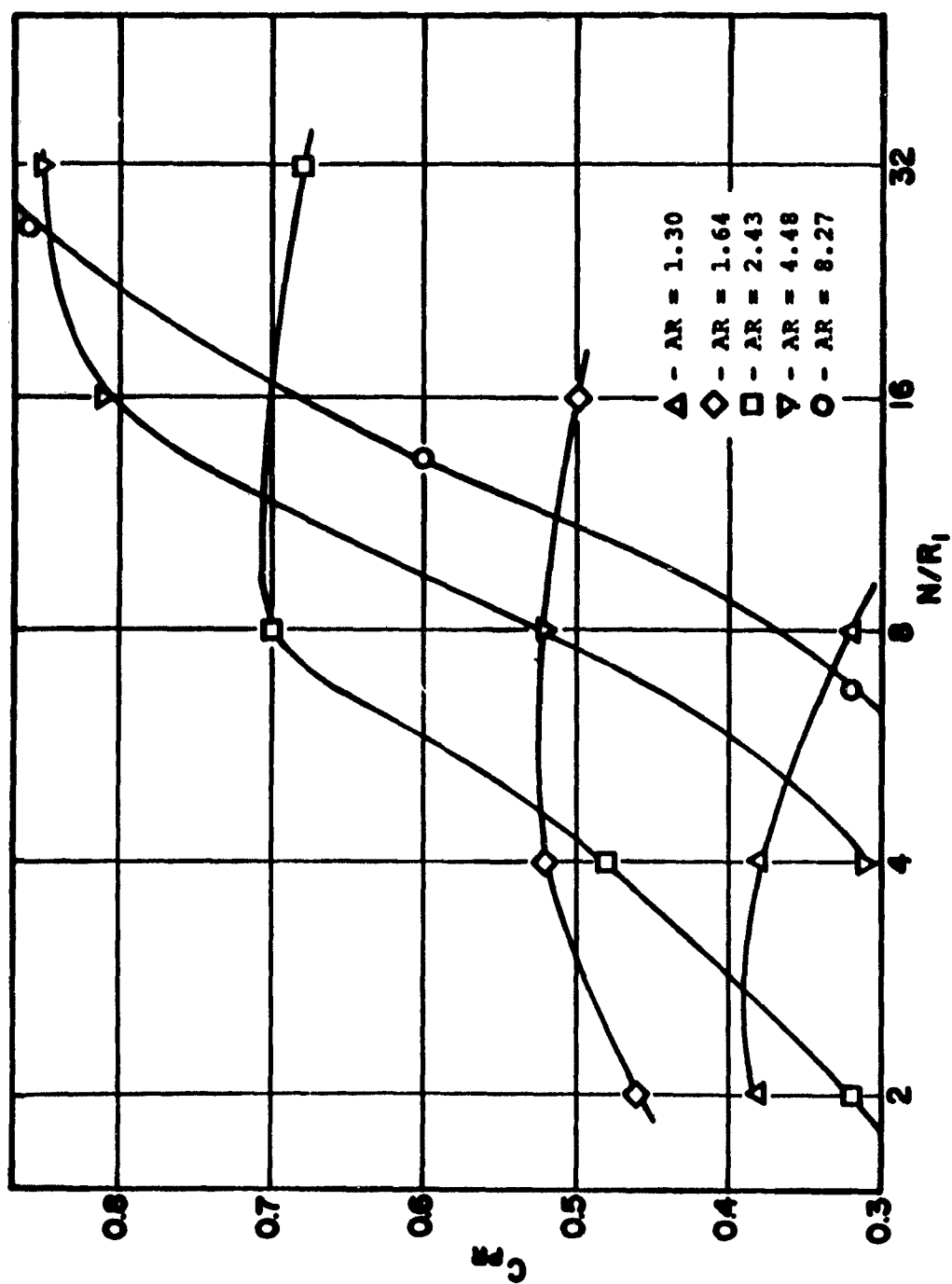
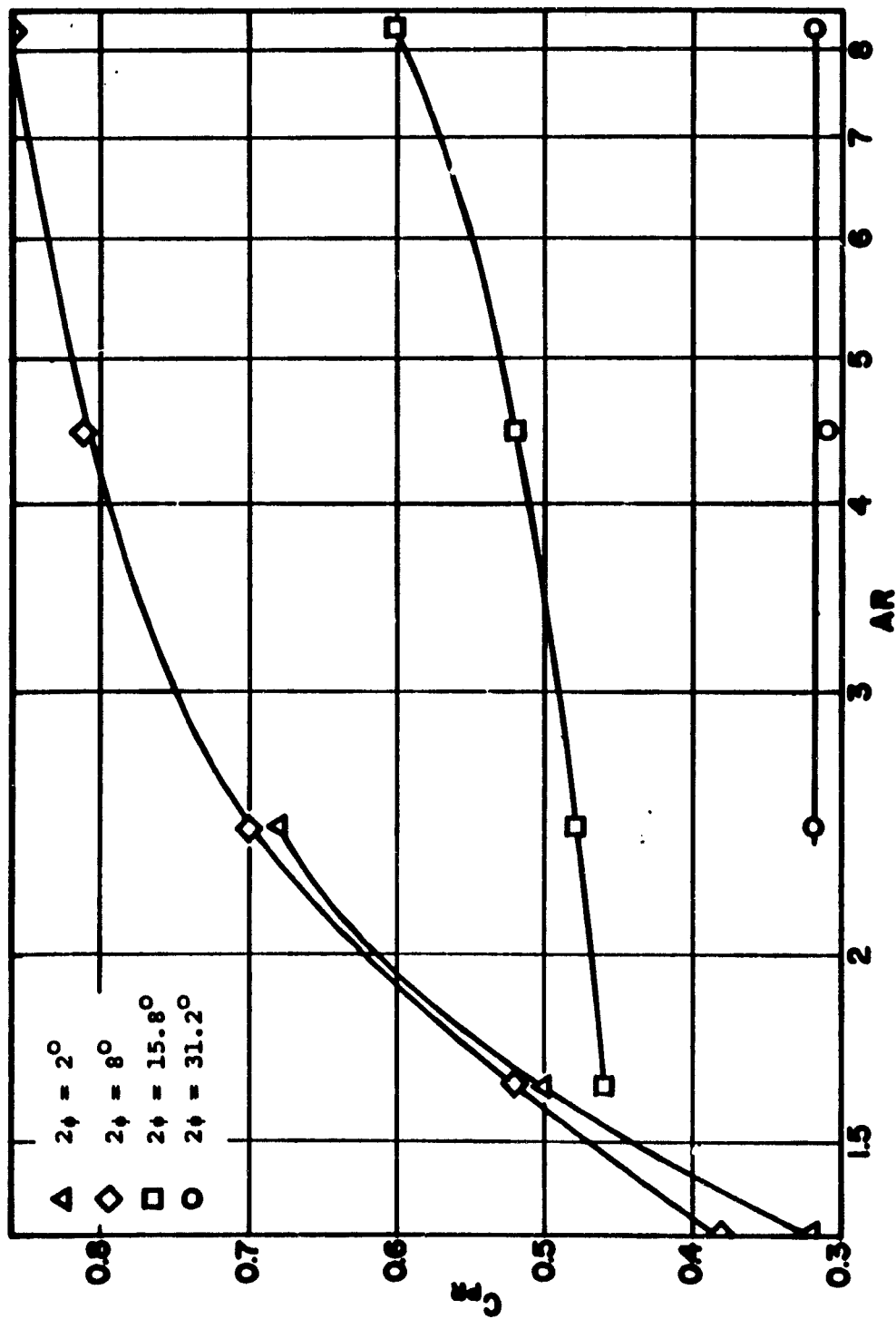


Figure B1. C_{PR} vs N/R_1 at Constant AR for $M_1 = 0.25$

Figure B2. C_{PR} vs AR at Constant 2ϕ for $M_1 = 0.25$

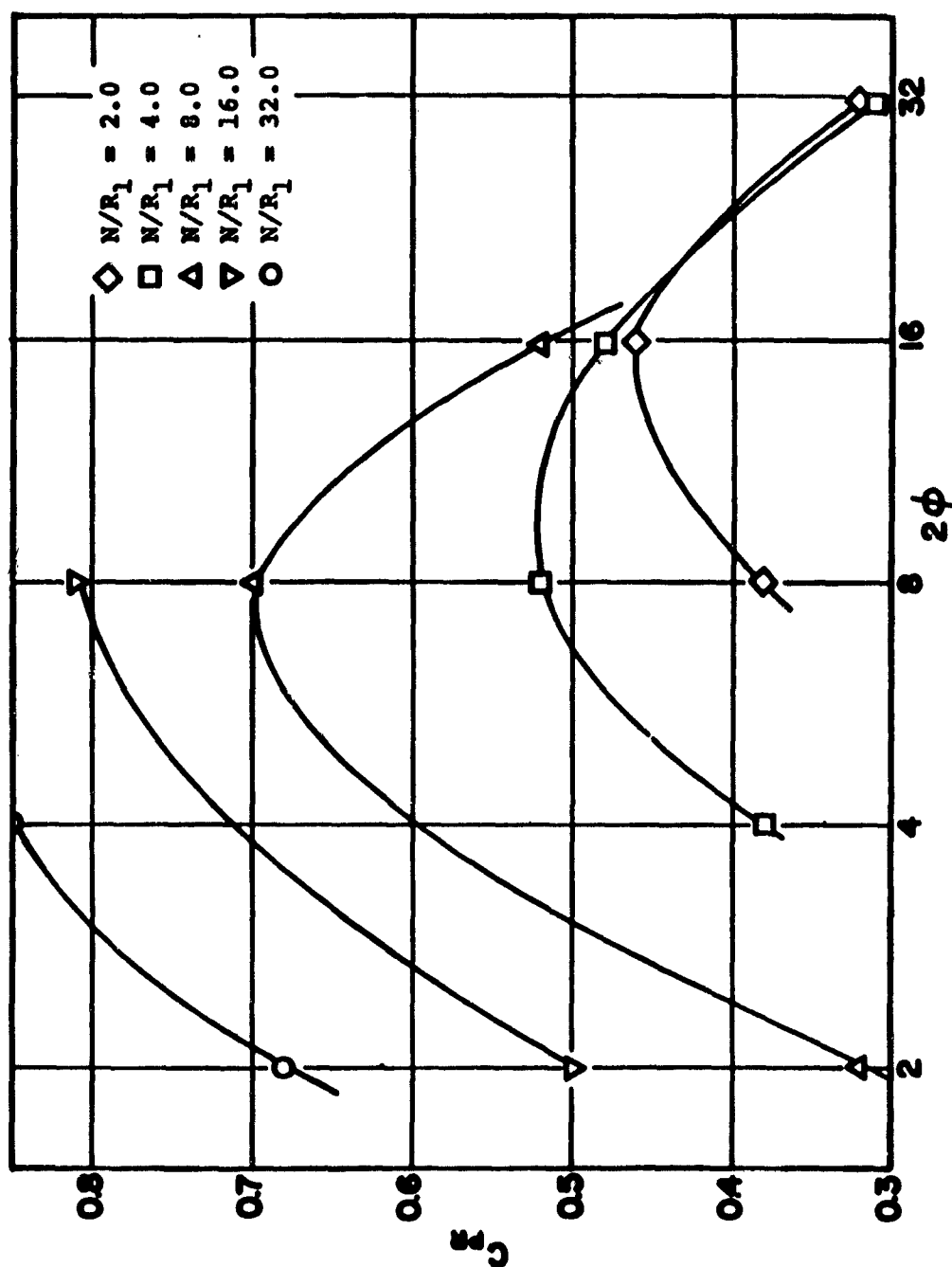


Figure B3. C_{PR} vs 2ϕ at Constant N/R_L for $M_L = 0.25$

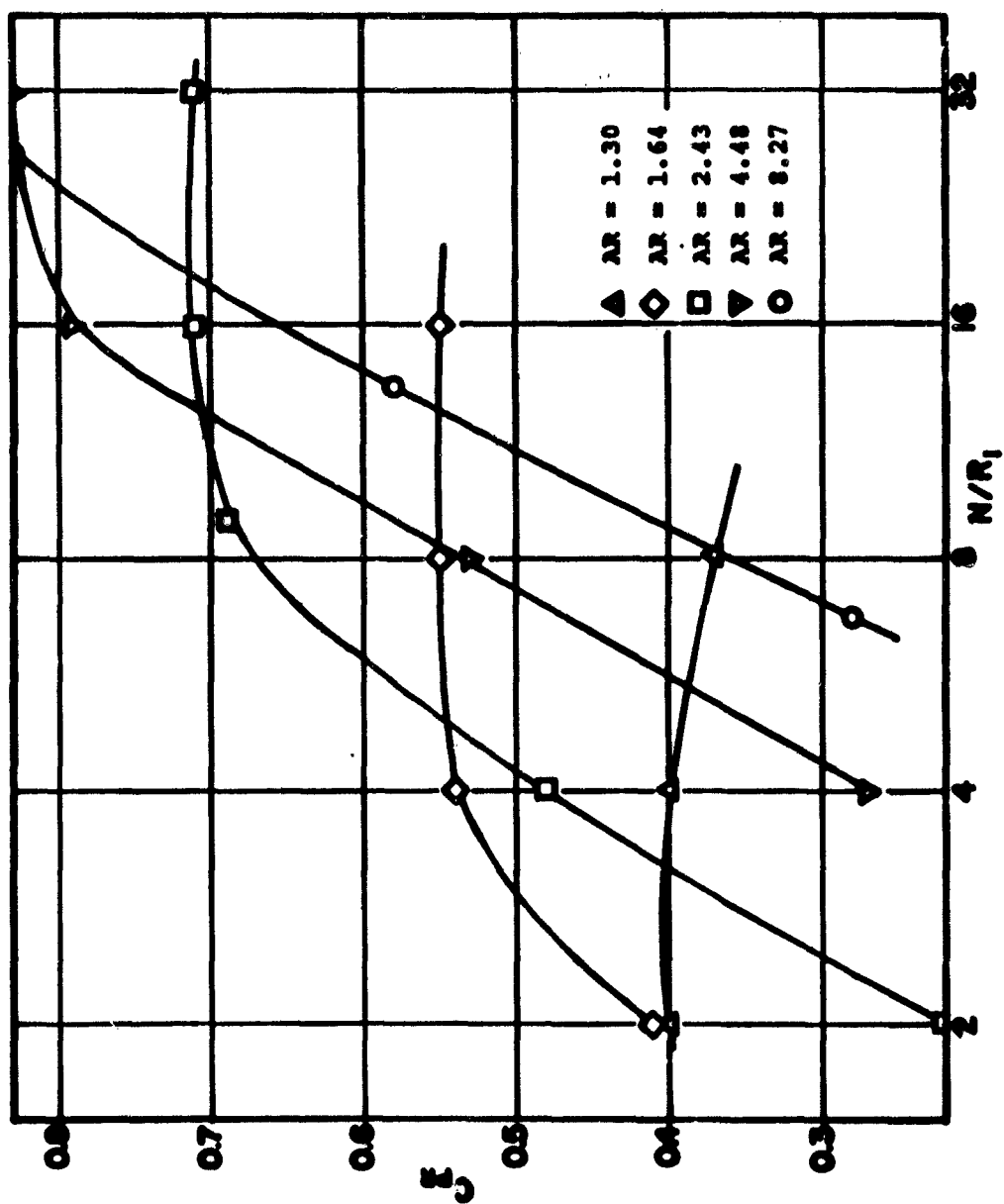
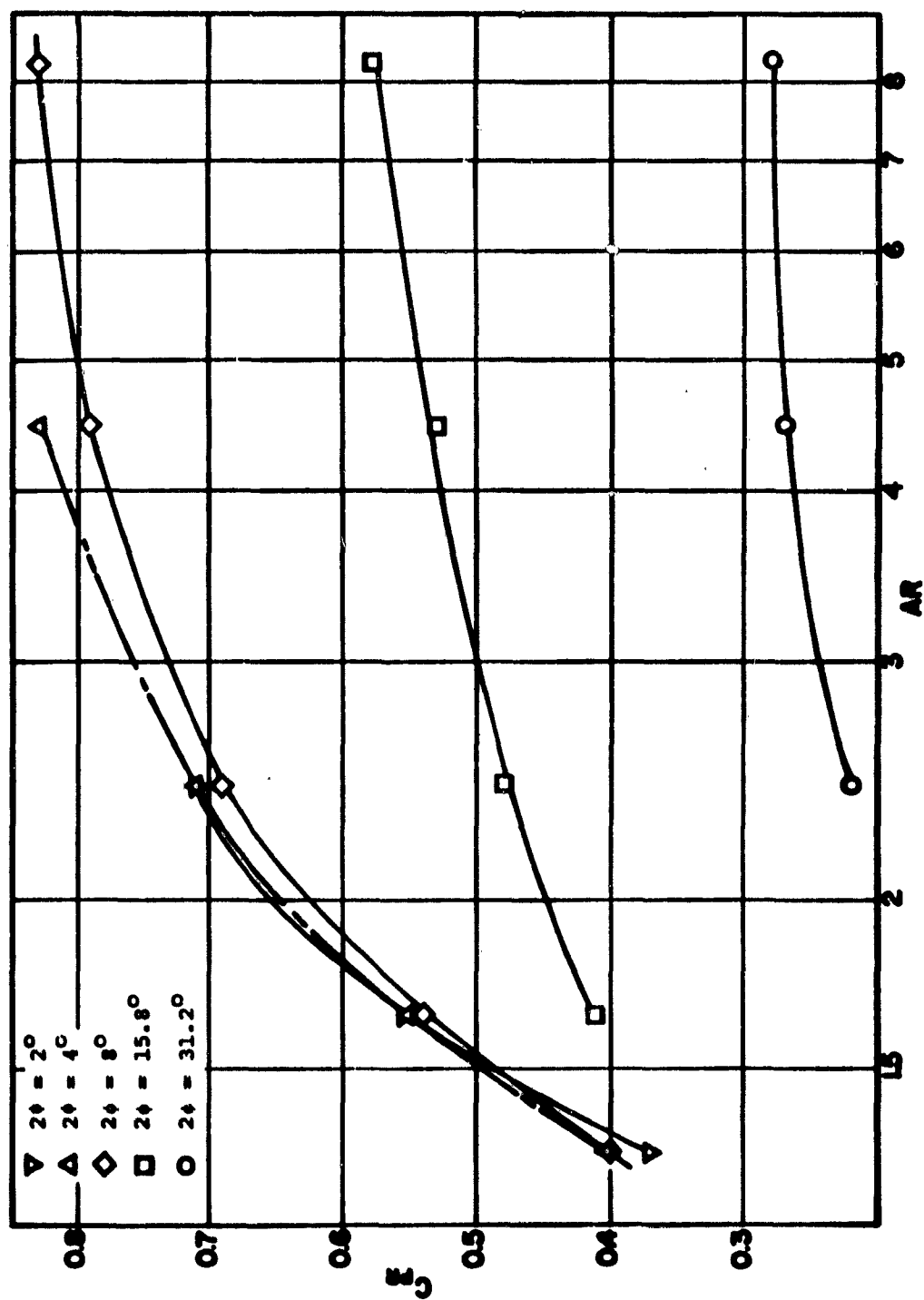


Figure B4. C_{PR} vs N/R_1 at constant AR for $M_1 = 0.55$

Figure B5. C_{pR} vs AR at Constant 2ϕ for $M_1 = 0.55$

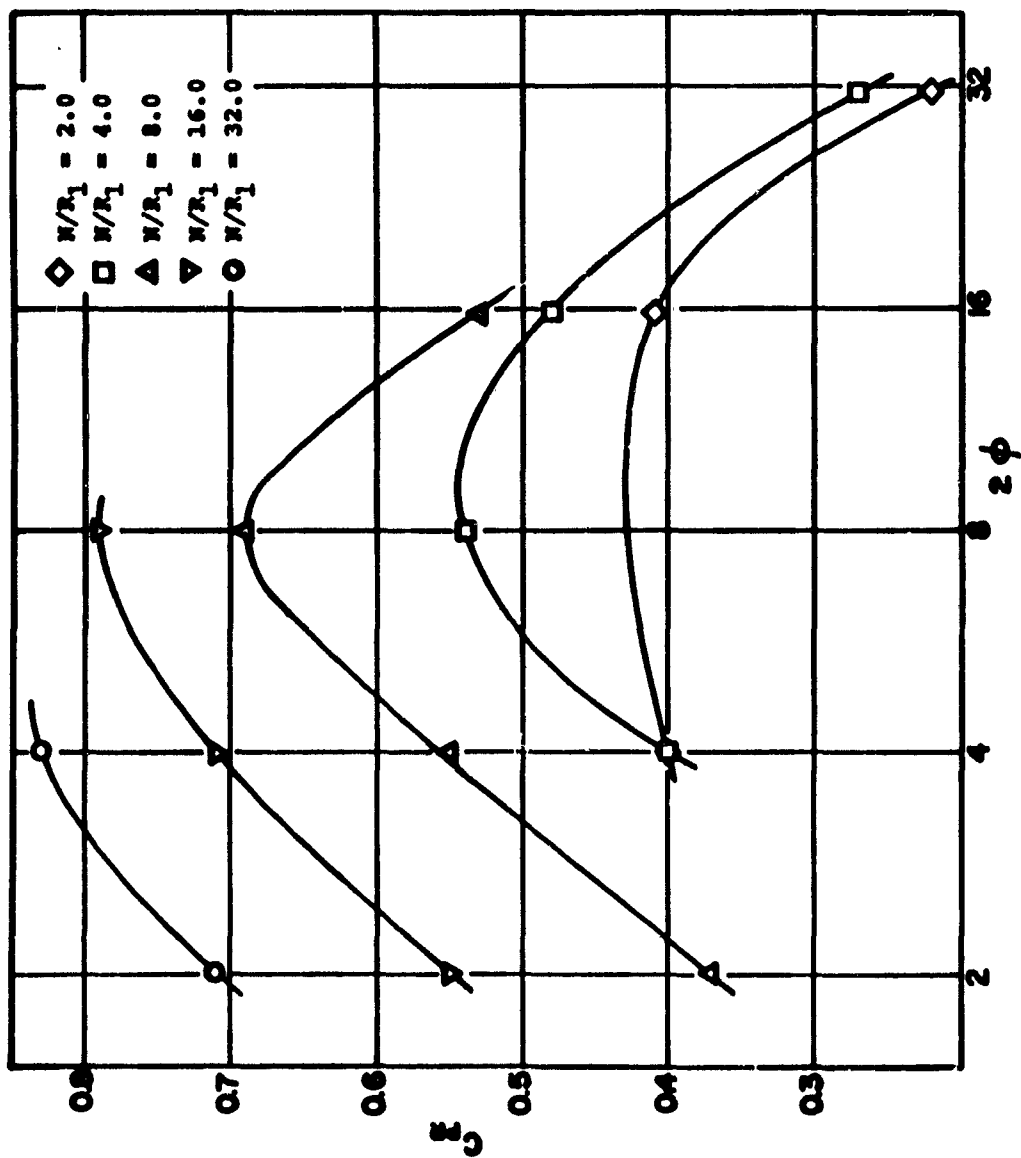


Figure B6. C_{pR} vs 2ϕ at constant N/R_1 for $M_1 = 0.55$

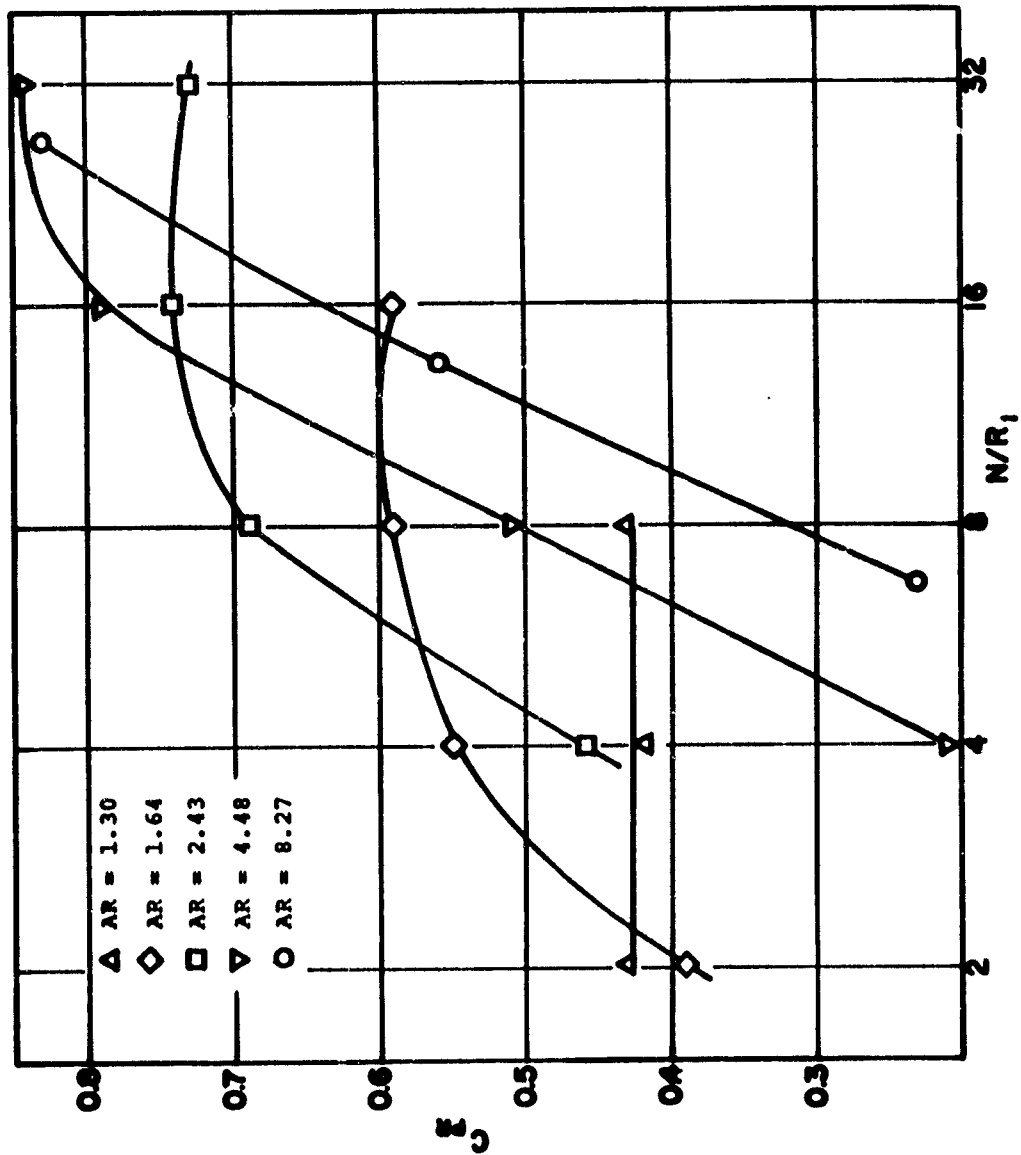
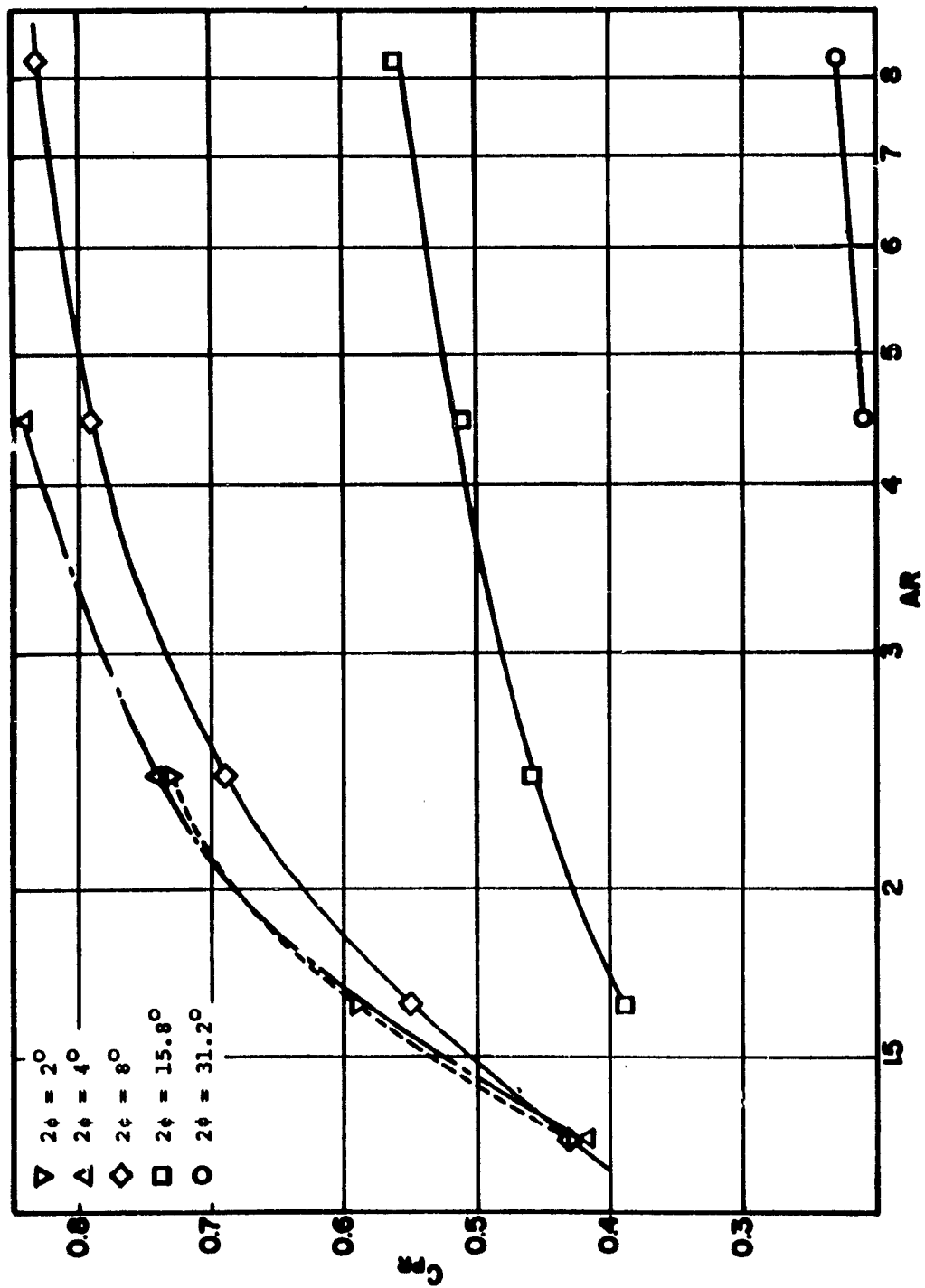


Figure B7. C_{pR} vs N/R_1 at constant AR for $M_1 = 0.70$

Figure B8. C_{pr} vs AR at constant 2ϕ for $M_1 = 0.70$

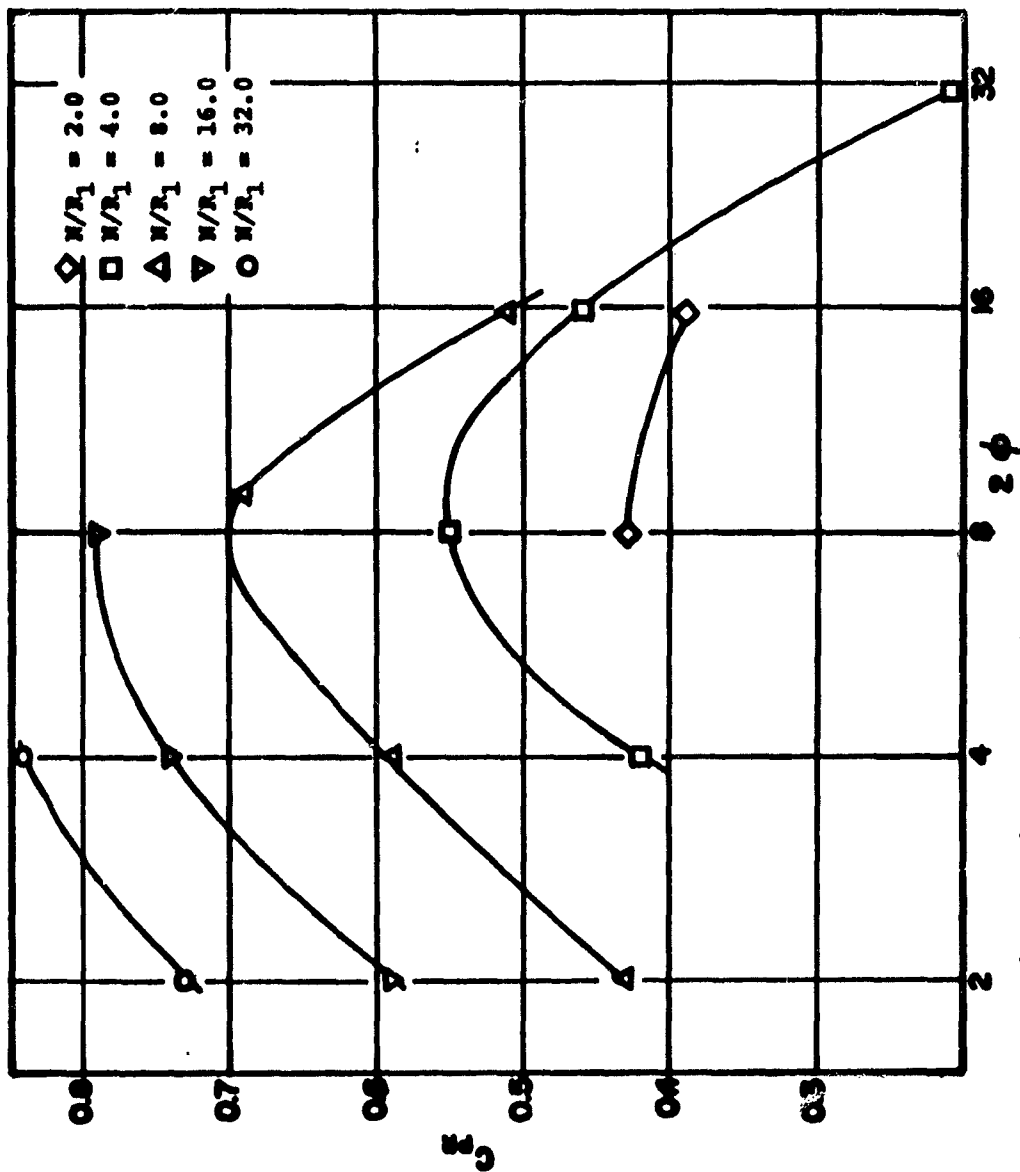


Figure B9. C_{PR} vs 2ϕ at Constant N/R_1 for $M_1 = 0.70$

Table B.1 Diffuser Performance at Selected Mach Numbers.
 Tabulated data taken from plots of C_{PR} vs M_1 .

θ degrees	N/R_1	AR	C_{PR}		
			$M_1 = 0.25$	$M_1 = 0.55$	$M_1 = 0.70$
2.0	8.0	1.30	.32	.37	.43
2.0	16.0	1.64	.50	.55	.59
2.0	32.0	2.43	.68	.71	.73
4.0	4.0	1.30	.38	.40	.42
4.0	8.0	1.64		.55	.59
4.0	16.0	2.43		.71	.74
4.0	32.0	4.48	.85	.83	.84
8.0	2.0	1.30	.38	.40	.43
8.0	4.0	1.64	.52	.54	.55
8.0	8.0	2.43	.70	.69	.69
8.0	16.0	4.48	.81	.79	.79
8.0	26.8	8.27	.86	.83	.83
15.8	2.0	1.64	.46	.41	.39
15.8	4.0	2.43	.48	.48	.46
15.8	8.0	4.48	.52	.53	.51
15.8	13.4	8.27	.60	.58	.56
31.2	2.0	2.43	.32	.22	
31.2	4.0	4.48	.31	.27	.21
31.2	6.7	8.27	.32	.28	.23

APPENDIX C. Method of Obtaining Performance Maps

The diffuser performance maps (contours of constant C_{PR} on coordinates of $AR-1$ vs N/R_1) of Figures 16, 17, and 18 have been drawn from the cross-plots given in Appendix B; the data used in the cross-plots is tabulated in Tables B-1.

For a given inlet Mach number the data of Table B-1 has been plotted as C_{PR} vs 2ϕ at constant N/R_1 . (For $M_1 = 0.25$ these plots are shown in Figure B1, B2 and B3 respectively.) From each of these plots one can then obtain a series of diffuser geometries which will yield a given value of C_{PR} . Consider the case of $M_1 = 0.25$; suppose further that we are interested in obtaining diffuser geometries for which $C_{PR} = 0.5$. From Figure B1 we see that there are five conical diffuser geometries for which we would expect $C_{PR} = 0.5$; from Figure B2 we obtain three additional geometries; Figure B3 yields another five geometries. Thus the contour of $C_{PR} = 0.5$ on the performance map of Figure 15 is based on a total of thirteen points.

By following this procedure sufficient points were obtained to enable smooth contours of constant C_{PR} to be established on the performance maps.

APPENDIX D. Discussion of Diffuser Choking

The results of the present study indicate that for a given inlet Mach number, diffuser performance may be multi-valued, i.e. there may be a value of the inlet Mach number for which the slope of the C_{PR} vs M_1 curve becomes infinite. This is not surprising. In fact it can be shown that theoretically this occurs for an inlet Mach number of unity.

The diffuser performance is given by

$$C_{PR} = \frac{P_2 - P_1}{\frac{1}{2} \rho_1 U_1^2} = \frac{\left(\frac{P_2}{P_1} - 1\right)}{\frac{1}{2} \frac{\rho_1}{P_1} U_1^2}$$

Treating air as an ideal gas, then $P_1 = \rho_1 R T_1$, and the sonic velocity is given by $c_1 = \sqrt{k R T_1}$

Thus we can write

$$C_{PR} = \frac{\left(\frac{P_2}{P_1} - 1\right)}{\frac{k M_1^2}{2}}$$

where k is the specific heat ratio ($\gamma=1.4$ for air).

In the present study the diffuser is preceded by a converging section (fig. 3); the flow from the diffuser discharges to the atmosphere. Thus for a given diffuser there is a wide range of upstream stagnation pressures which will give a throat Mach number of unity. Since, $P_2 = \text{constant}$, then with $M_1 = 1$, the diffuser inlet pressure, P_1 , can be

increased arbitrarily by increasing the upstream stagnation pressure; thus the slope of the C_{PR} vs M_1 curve becomes infinite at a value of $M_1 = 1$.

The data indicate that this sudden sharp decrease in diffuser performance occurred at a measured inlet Mach number less than unity (but greater than $M_1 = 0.90$). This may be expected if one considers the location of the inlet pressure tap. For ease of construction the inlet pressure tap (for measurement of P_1) was located in the straight section of the inlet nozzle a distance of 1.12 inches upstream of the diffuser throat. If one considers the flow between the pressure tap and the diffuser throat as Fanno line flow, small frictional effects will cause relatively large increases in the Mach number for a measured Mach number $M_1 \geq 0.90$. That the throat velocity is sonic for $M_1 \geq 0.90$ can also be demonstrated from consideration of the one-dimensional isentropic flow tables. For $M_1 = 0.90$, $A_1/A^* = 1.0088$ where A^* is the flow area at which the Mach number is unity. Thus a very small increase in the boundary layer displacement thickness between the measuring station and the diffuser throat is sufficient to give a throat Mach number of unity.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Purdue Research Foundation Purdue University		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP NA	
3. REPORT TITLE An Experimental Investigation on the Effect of Subsonic Inlet Mach Number on the Performance of Conical Diffusers			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical Report - February 1966			
5. AUTHOR(S) (Last name, first name, initial) Van Dewoestine, Robert V. Fox, Robert W.			
6. REPORT DATE February 1966		7a. TOTAL NO. OF PAGES 68	7b. NO. OF REFS 8
8a. CONTRACT OR GRANT NO. DA-31-124-ARO-D-138		8b. ORIGINATOR'S REPORT NUMBER(S) Technical Report FMTR-66-1	
a. PROJECT NO. 20014501B330			
c.		9a. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) 4332.4	
d.			
10. AVAILABILITY/LIMITATION NOTES Distribution of this document is unlimited.			
11. SUPPLEMENTARY NOTES None		12. SPONSORING MILITARY ACTIVITY U. S. Army Research Office-Durham. Box CM, Duke Station Durham, N. C. 27706	
13. ABSTRACT Experiments have been performed to determine the effect of subsonic inlet Mach number on diffuser performance and flow regimes for a wide range of conical diffuser geometries. For incompressible flow the line of first appreciable stall is essentially that found by McDonald and Fox. As the Mach number is increased, the flow tends more toward separation in all cases. Diffuser performance maps are presented for three different inlet Mach numbers ($M_1 = 0.25, 0.55, 0.70$). There is no significant variation in the location of the line of maximum performance at constant length to inlet radius ratio with inlet Mach number.			

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLL	WT	ROLL	WT	ROLL	WT
Conical Diffusers Incompressible Flow Compressible Flow Flow Regimes						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (either by the originator or by the sponsor) also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.